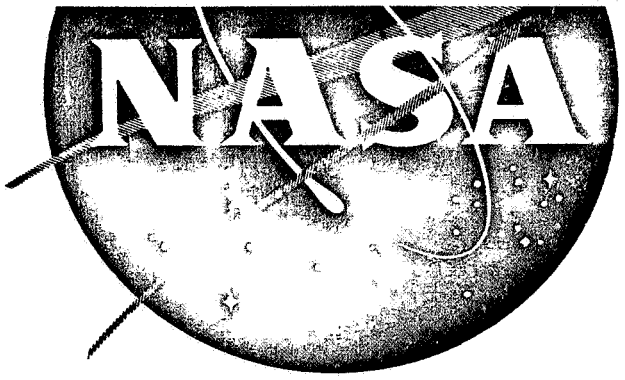
MSC-03909

101052

HABITABILITY DATA HANDBOOK

VOLUME 2

ARCHITECTURE AND ENVIRONMENT



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER

PREFACE

The Habitability Data Handbook is a collection of data in six volumes which include requirements, typical concepts, and supporting parametric data. The handbook provides an integrated data source for use in habitability system planning and design, intersystem trade-offs, and interface definition. The following volumes comprise the Habitability Data Handbook:

Volume	Title
1	Mobility and Restraint
2	Architecture and Environment
3	Housekeeping
4	Food Management
5	Garments and Ancillary Equipment
6	Personal Hygiene

This volume provides architectural and environmental data applicable to extraterrestrial habitats and vehicles.

These data are considered preliminary and are predominantly derived from analytical and terrestrial sources and in general lack zero-g verification.

CONTENTS

CONTENTS (CONTINUED)

CONTENTS (CONCLUDED)

1.0 INTRODUCTION

1.1 PURPOSE

The architectural and environmental data and concepts presented in this handbook have been selected and developed for the purpose of establishing desirable standards of habitability for extraterrestrial habitats and vehicles. The minimum values given are to be used only when power is critical and performance can be compromised or, in emergency situations. It should also be noted that the designer could select all optimum environmental values for a specific area, but because of mission objectives or the crew's personal taste, the area is not the optimum habitat. Therefore, the criteria, as presented, are not intended to be construed as absolute requirements, but are to be used as a guideline in determining the best habitat for the designer's particular mission objective.

So that the standards would have a broad range of application to extraterrestrial vehicles over the next twenty years, all standards of criteria are plotted for crews from 2 to 100 and for mission durations from 7 to 1040 days. The establishment of these criteria was made with the consideration of personnel first, equipment second.

1.2 MAJOR INTERFACE AREAS

The architectural layouts and environmental systems interface with the following habitability areas:

- Food Management (Volume 4)
- Personal Hygiene (Volume 6)
- Mobility and Restraint (Volume 1)
- Housekeeping (Volume 3)
- Garments and Ancillary Equipment (Volume 5)

Food storage and preparation equipment data which support architectural design evaluations are presented in the Food Management volume. The design considerations for the architectural and environmental layout of a bathroom or grooming area interface with the equipment and systems data given in the Personal Hygiene volume. The architectural consideration

for room area and volume would use the data on waste volumes given in the Housekeeping volume. The environmental aspects of lighting, acoustics, temperature and color, as well as the architectural layout, are all influenced by the engineering data and concepts given in the other habitability volumes.

1.3 HANDBOOK USE

1.3.1 General Discussion. Section 2.0 of the handbook is a guide defining how the elements of habitability may be applied to specific mission activities and their combinations. Sections 3.0 and 4.0 are used to gain a basic understanding of the nature and importance of the given habitability elements. These elements are:

3.1 Lighting	4.1 Texture and Design
3.2 Acoustics	4.2 Hygiene
3.3 Temperature	4.3 Dual Room Usage
3.4 Color	4.4 Gravity
3.5 Volume	4.5 Interrelated Environments

An understanding of these elements is an ingredient essential to making decisions regarding the application of concepts and guidelines presented in this and the other habitability volumes, to actual mission design situations.

Section 2.0, Architectural Design Criteria, contains general guidelines and examples pertaining to the application of the data and concepts presented in Sections 3.0 and 4.0 to specific activity areas. It is emphasized that these guidelines are general in nature and must be used with discretion.

Paragraph 1.3.3 of this section presents a system for applying the concepts and guidelines presented in Sections 2.0, 3.0 and 4.0 to the development of rough mission models.

1.3.2 Mission Model Development. The following example illustrates a systematic approach to provide a quick method of computing approximate habitability needs.

1.3.2.1 Procedure. To utilize this volume to develop an approximate model for a specific mission the following six steps are used:

1. Determine the mission compatibility rating.

2. Determine the acceptable compartmentation level and suitable activity combinations.
3. Figure the area requirements for the individual activities.
4. Apply the efficiency factor to activity area requirements.
5. Figure the area requirements for combined activities.
6. Determine which activities in each activity combination has the most stringent habitability standards for lighting, acoustics, temperature and color.

1.3.2.2 Sample Calculation

Example mission parameters:

Crew size - 12
Mission duration - 90 days per crew
Gravity level - zero
Atmosphere - 14.7 psia O_2-N_2
Station Life - 10 years

- Step 1: Mission Compatibility Rating - Refer to Figure 1-1 to determine the mission compatibility rating. As shown by the dotted lines, the mission compatibility rating for the sample mission is 2.

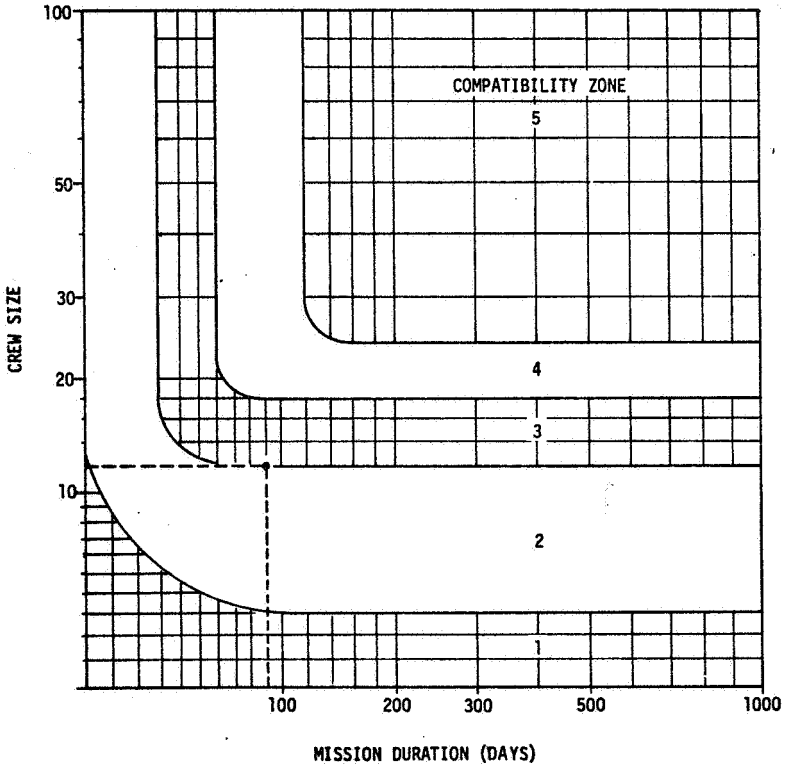


Figure 1-1. Compatibility Rating As a Function of Crew Size and Mission Duration

- Step 2: Work Sheet Selection - Select the work sheet appropriate to the mission compatibility level. Work sheets for computing approximate volumetric requirements and for noting dominant lighting, acoustic, temperature and color standards for each area are provided on pages 1-5 and 1-6. The two work sheets are laid out to reflect the compartmentation recommendations for a specific compatibility level as established in Section 4.3, Dual Room Usage. For the sample mission, a compatibility zone 2 chart is shown in Figure 1-2 filled in with data derived from Section 2.0.

- Step 3: Apparent Area - The area requirements for the individual activities are recorded by the user in the left hand column. These figures are determined by referring to the appropriate crew areas in Section 2.0. Because of the general nature of the handbook, area figures are provided for only those areas in which furniture units were not mission dependent (unknown machinery, etc.).

- Step 4: Actual Area - By multiplying the apparent area need for each activity by the efficiency figure listed in the second column from the left, the actual area need for that activity is determined.

- Step 5: Total Area - The actual area needs are now combined to determine the total area needs for each activity combination. These figures are added together and multiplied by the average floor to ceiling height to determine the rough volumetric requirements for all of the activities considered.

- Step 6: Dominant Environmental Standards - Refer to Section 2.0 to determine those areas within each activity combination which have the most stringent standards for lighting, acoustics and temperature. The activity having the dominant standard in each area should be checked in the appropriate column. The dominant activity in each activity combination is listed first on the worksheet within each activity group. The color scheme for a combined activity area is generally selected to complement the character of the dominant activity in the area.

1.3.2.3 Crew Areas and Usage by Mission Model. Tables 1-1 and 1-2 are included to provide a reference for crew time by area and mission model.

MISSION WORKSHEET

MISSION PARAMETERS:

Crew Size: 12 Gravity Level: 0

Mission Duration: 90 DAYS/CREW 10 YR. TOTAL Atmosphere: 14.7 PSI

Activity Combinations	Apparent Area (ft^2)	Efficiency Factor	Actual Area (ft^2)	Total Area (ft^2)	Dominant Environmental Standards		
					Lighting	Acoustics	Temp.
Personal Quarters	558	1.0	558		X	X	X
Study	-	.0					
Locker Room	-	.0		558			
Dining Room	180	1.0	180				
Recreation	-	-					
Theater	-	.0					X
Conference Room	-	.0					
Briefing Room	-	.0					
Chapel	-	.0					
Library	12	.35	4.2		X	X	
Lounge	64	.5	32	216.2			
Gym	96	1.0	96	96			
Passageway	-	1.0					
Galley	-	1.0	X		X	X	
Snack Bar	-	.0	X				X
Laundry	-	1.0	X				
Dispensary	76	1.0	76		X	X	X
Barbershop	-	.0		76			
Bathroom	157.5	1.0	157.5	157.5			
Storage	-	-	X			X	
Supply	-	-	X		X		X
Communications		-	X		X	X	X
Control		-	X				
Computer		-	X				
Equipment		-	X				X
Shop		-	X			X	
Maintenance		-	X		X		
Office		-	X				X
Laboratory		-	X		X		
Photography		-	X			X	
Animal Housing		-	X				
Agricultural Study Area		-					
Docking		-			X	X	
Air Locks		-					X
Power		-					

Figure 1-2. Example Mission Worksheet (Page 1 of 2)

MISSION WORKSHEET

MISSION PARAMETERS:

Crew Size: _____ Gravity Level: _____

Mission Duration: _____ Atmosphere: _____

Activity Combinations	Apparent Area (ft^2)	Efficiency Factor	Actual Area (ft^2)	Total Area (ft^2)	Dominant Environmental Standards		
					Lighting	Acoustics	Temp.
Personal Quarters		1.0					
Study		.0					
Locker		.0					
Dining Room		1.0					
Recreation		-					
Theater		.0					
Conference Room		.0					
Briefing Room		.0					
Chapel		.0					
Library		.35					
Lounge		.5					
Gym		.2					
Passageway		1.0					
Galley		1.0					
Snack Bar		.0					
Laundry		1.0					
Dispensary		-					
Barbershop		-					
Bathroom		-					
Storage		-					
Supply		-					
Communications		-					
Control		-					
Computer		-					
Equipment		-					
Shop		-					
Maintenance		-					
Office		-					
Laboratory		-					
Photography		-					
Animal Housing		-					
Agricultural Study Area		-					
Docking		-					
Air Locks		-					
Power		-					

Figure 1-2. Example Mission Worksheet (Page 2 of 2)

Table 1-1. Frequency of Usage by Mission Model

Area	Hours per Day in Crew Areas					
	Logistics Spacecraft		Earth Orbital Space Station		Planetary Space Vehicle	
	Nom. Work-day	Off-Duty Day*	Nom. Work-day	Off-Duty Day	Nom. Work-day	Off-Duty Day
Living Areas						
Lounge			1	4	1	4
Recreation			1	3	1	3
Passageways	N		N	N	N	N
Study or library			0.5	2	0.5	2
Bedroom	8		9	9	9	9
Bathroom	1		1	1	1	1
Conference			N	0	N	0
Food Preparation and Serving						
Kitchen	2		1	1	1	1
Dining room	2		2	2	2	2
Food storage	N		N	N	N	N
Snack bar			N	N	N	N
Services						
Laundry			0	1	0	1
Briefing room	0.5		0.5	0	0.5	0
Locker room			N	N	N	N
Theater			0	N	0	N
Dispensary			N	N	N	N
Chapel			0	N	0	N
Barbershop			0	N	0	N
Supply			0	N	0	N
Maintenance			N	N	N	N
Equipment			N	N	N	N
Gym			0	1	0	1
Power			N	0	N	0
Work Areas						
Control Room	10		8	0	8	0
Airlocks	N		N	0	N	0
Inspection	N		N	0	N	0
Photographic support			N	N	N	N
Animal housing			N	0	N	0
Docking	N		N	0	N	0
Agricultural study			N	0	N	0
Computer			N	0	N	0
Offices			N	0	N	0
Laboratory			N	0	N	0
Shops			N	0	N	0
Communications			N	0	N	0

*It is assumed that no off-duty day will occur on Logistics Spacecraft

N = nominal time period (less than 2 hours per day - time in area would depend on duties for that day)

Table 1-2. Crew Areas by Mission Model

Area	Mission Models		
	Logistics Spacecraft	Earth Orbital Space Station	Planetary Space Vehicle
Living Area			
Lounge	NR	D	D
Recreation	NR	R	R
Passageways	D	R	R
Study or library	NR	R	D
Bedroom	D	R	R
Bathroom	D	R	R
Conference	NR	D	D
Food Preparation and Service			
Kitchen	D	R	R
Dining room	D	R	R
Food storage	R	R	R
Snack bar	NR	D	D
Services			
Laundry	NR	R	R
Briefing room	NR	D	D
Locker room	NR	D	D
Theater	NR	D	D
Dispensary	NR	R	R
Chapel	NR	D	D
Barbershop	NR	R	R
Supply	NR	R	D
Maintenance	NR	R	R
Equipment	NR	R	R
Gym	NR	D	D
Power	NR	R	R
Work Areas			
Control room	R	R	R
Airlocks	R	R	R
Inspection	NR	D	D
Photographic support	NR	R	D
Animal housing	NR	D	D
Docking	R	R	R
Agricultural study	NR	D	D
Computer	NR	R	D
Offices	NR	D	D
Laboratory	NR	R	D
Shops	NR	R	D
Communications	NR	D	D

LEGEND: R = required
NR = not required
D = desirable but not absolutely required

1.4 NOMENCLATURE

AI	=	Articulation Index
ρoC	=	Characteristic Impedance
Clo	=	Clothing Insulation Value
CU	=	Coefficient of Utilization
CW	=	Cool White
CWX	=	Deluxe Cool White
dB	=	Decibel
ft c	=	Footcandle
HID	-	High Intensity Discharge
Hz	=	Hertz
IES	=	Interval Environment Simulator
LDD	=	Luminaire Dirt Depreciation
LLD	=	Lamp Lumen Depreciation
MAF	=	Minimum Audible Field
MAP	=	Minimum Audible Pressure
NC	=	Noise Criteria
NCA	=	Alternate Noise Criteria
OB	=	Octave Band
PB	=	Phonetically Balanced
PSIL	=	Preferred Frequency Speech Interference Level
PWL	=	Sound Power Level
SIL	=	Speech Interference Level
SPL	=	Sound Pressure Level
TTS	=	Temporary Threshold Shift
UV	=	Ultraviolet
WOB	=	Weighted Octave Band
WW	=	Warm White
WWX	=	Deluxe Warm White

1.5 ARCHITECTURAL SYMBOLS


Drawer chest


Closet


Stowed bed


Deployed bed


Chair


Shower stall


Toilet


Urinal


Wash basin


Wall mirror


Table with two chairs


Table with four chairs


Movie screen

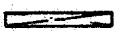

Table with lamp


Sofa


Easy chair


Theater seat


Small table


Bookcase or storage shelves


Barber chair


Desk or table with chair


Table with chair - shelves above


Table with seven chairs

2.0 ARCHITECTURAL DESIGN CRITERIA

Habitability criteria standards are presented in this section by crew area for a broad range of mission parameters. The description of each area, to a great extent, determined the various standards and concepts. The activity of the crew areas determined the metabolic rate for temperature considerations and lighting requirements and is listed as either high, moderate, or low. The mood to be created in the room determined such factors as temperature, color, lighting, and acoustics. Therefore, the mood characteristics are either restful, mental concentration, or physical activity. The social factor determined such items as hygiene and mess requirements, volumetric requirements, and dual room usage. For each standard and concept, all of the descriptive terms must be combined to achieve the optimum standard or concept. The crew areas discussed and their location are provided in the following list:

Crew Areas

2.1 PERSONAL AREAS

2.1.1 Bedrooms.

Description: Mood: Restful, mental concentration
Activity: Low
Social Factor: Private with ability to have one or two guests

LIGHTING

Light Source: Incandescent and fluorescent

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	10-30	30-3

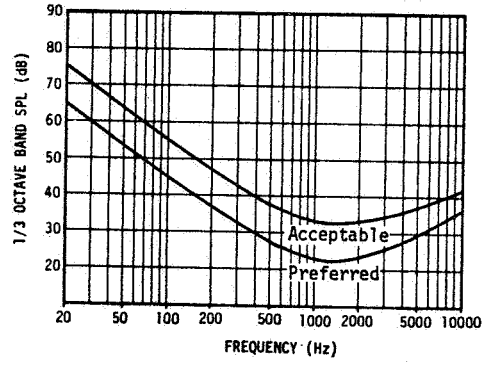
SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	60-90	90-60
Walls	20-50	60-15
Floors	15-35	40-10
Furniture	20-40	50-10
Draperies	15-60	60-15

Remarks: Individual reading lamps at head of each bed for personal use essential. General lighting level controllable (high-low) to adequately meet needs but not interfere with functions of other occupants. Atmosphere should be cool and relaxing.

ACOUSTICS

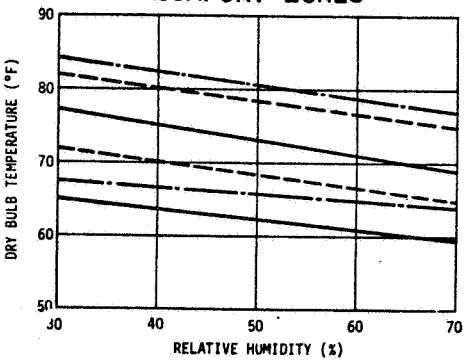
SOUND PRESSURE LEVEL



Remarks: Relaxation must be promoted, therefore intermittent and high-pitched noise sources must be eliminated. Thick carpets, drapes, and padded cloth furniture can be used to help trap noises.

TEMPERATURE

COMFORT ZONES



LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0 to 1.0
Air Flow Rate: 50 fpm
Metabolic Rate: 300 Btu/hr
Occupancy Time: 9 hrs/day

Bedroom - One man

EXAMPLE COLOR SCHEME

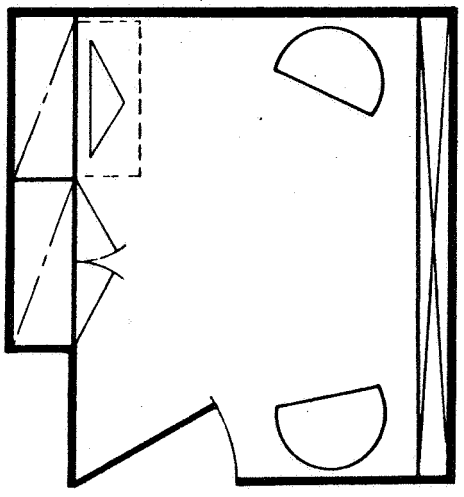
Color Effects: Cheering, relaxing

Dominant	MONOCHROMATIC		ANALOGOUS		Complementary Accents
	Subdominant	Subordinate	Subdominant	Subordinate	
3ba	2dc	14ne	13fe	13ne	2ic
		14pc	15fe	13pc	2ne
		14pl		13pl	2pc
				15ne	
				15pl	

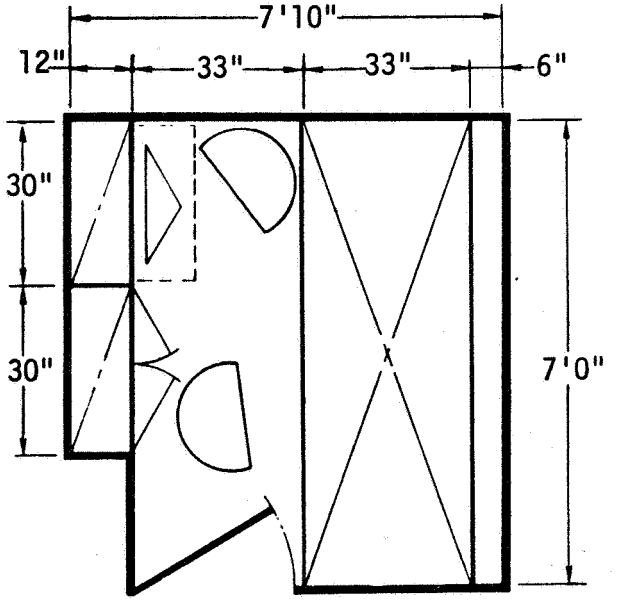
Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Both warm and cool schemes are recommended to allow for personal taste and provide for change. Provisions should be made for personal involvement if desired by occupant.

VOLUME

Remarks: The following recommendations are to be used for general guidance only; unless otherwise noted, the area recommendations pertain to an artificial gravity environment. It is recommended that all personnel be provided with a private room. The following area guidelines apply (ft^2): Gross = 45-50, Visual = 38, Net = 20-38 (fold-up bed). Ceiling Height = 6'6".



Bed Stowed



Bed Deployed

Bedroom - One and two men with Bath

EXAMPLE COLOR SCHEME

Color Effects: Cheering, relaxing

Dominant	MONOCHROMATIC		ANALOGOUS		Complementary Accents
	Subdominant	Subordinate	Subdominant	Subordinate	
3ba	2dc	17nc	3dc	15nc	2nc
		17lg		15la	2ng
		17pl		15pl	
				18lg	
				18pl	

Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Both warm and cool schemes are recommended to allow for personal taste and provide for change. Provisions should be made for personal involvement if desired by occupant.

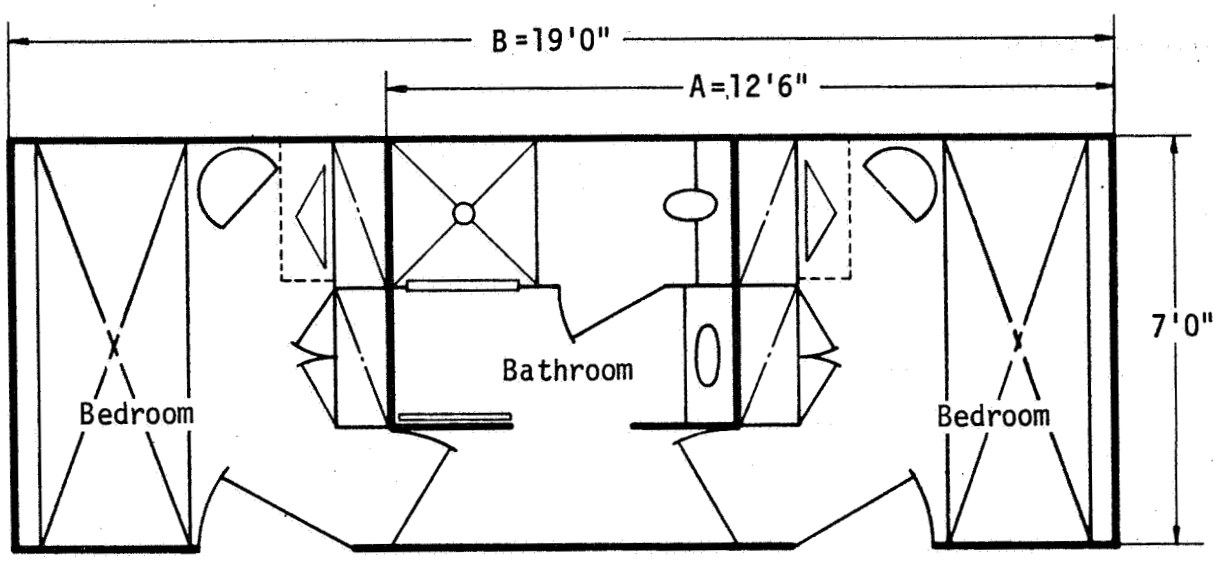
VOLUME

Remarks: The following recommendations are to be used for general guidance only; unless otherwise noted, the area recommendations pertain to an artificial gravity environment.

A: Suitable for deputy commander, crews 50-100. Gross area/man = 80 ft^2.

B: Suitable for deputy commander, crews 15-50, and management personnel, crews 50-100. Gross area/man = 70 ft^2.

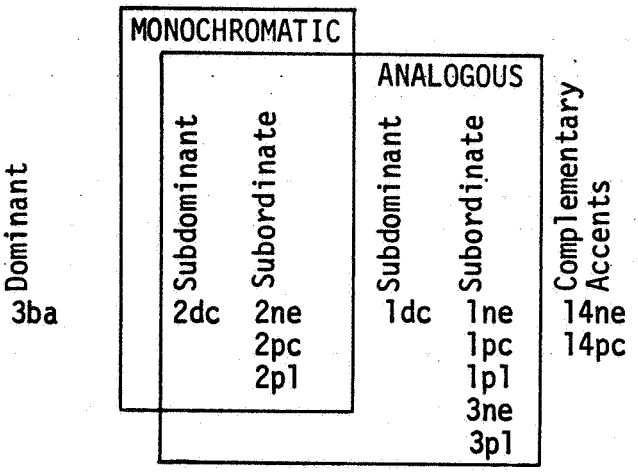
Ceiling Height = 6'6".



Bedroom - One man with Bath and Office

EXAMPLE COLOR SCHEME

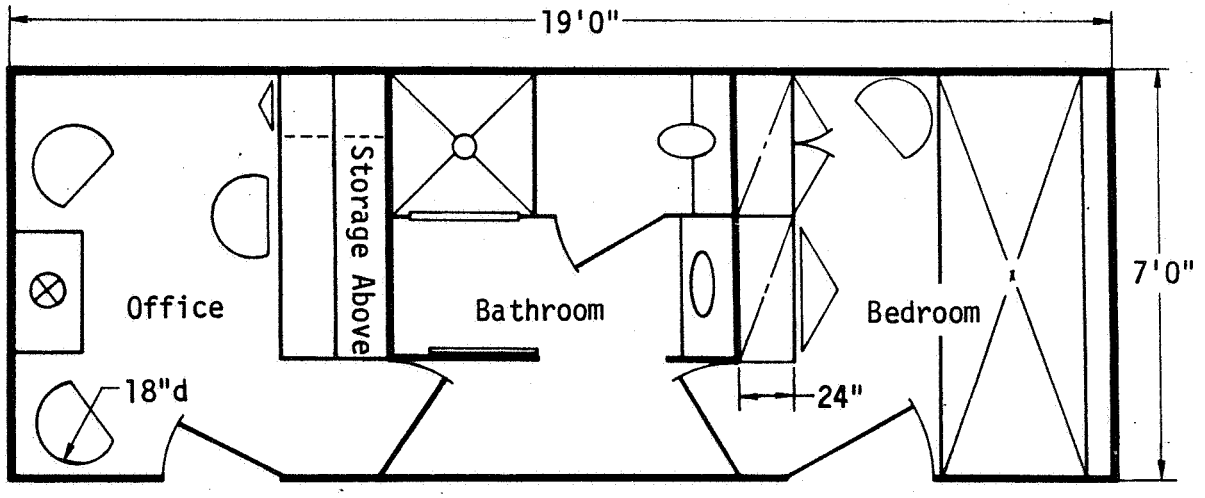
Color Effects: Cheering, relaxing



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only.
Both warm and cool schemes are recommended to allow for personal taste and provide for change. Provisions should be made for personal involvement if desired by occupant.

VOLUME

Remarks: The following recommendations are to be used for general guidance only; unless otherwise noted, the area recommendations pertain to an artificial gravity environment. The bedroom and bathroom sizes are constant for all missions; the office varies according to crew size. Gross area/crew size = 125.5 ft^2/6-30 crew; 133.5 ft^2/31-60 crew; 159.5 ft^2/61-100 crew. Ceiling height = 6'6".



2.2 PUBLIC AREAS

2.2.1 Dining Room.

Description: Mood: Restful
Activity: Moderate to low
Social Factor: Public

LIGHTING

Light Source: Incandescent and fluorescent

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	15-30	30-10

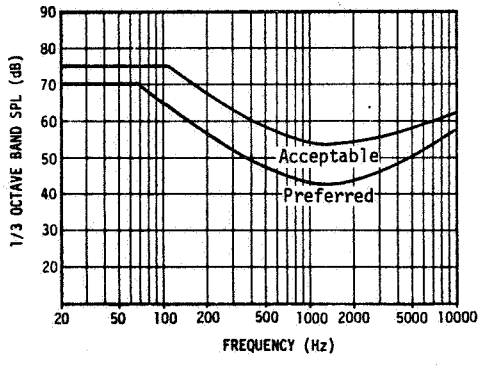
SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	60-90	90-60
Walls	35-60	60-35
Floors	15-35	35-10
Furniture	15-45	45-15
Draperies	15-60	60-15

Remarks: Two levels provided to suit the individual conditions: higher level for expediting meal serving time, lower level for subdued, relaxed dining. Higher level for maintenance program. Environment warm and inviting. Use of incandescent appropriate.

ACOUSTICS

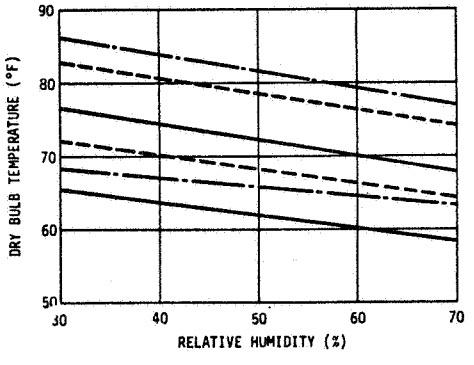
SOUND PRESSURE LEVEL



Remarks: High pitched noise sources must be avoided to preclude crew annoyance. Unlocalized noise sources are more annoying than noise sources that can be localized. From standpoint of noise control, ideal wall, ceiling and floor should be massive and porous. SIL levels below 60 dB should be maintained.

TEMPERATURE

COMFORT ZONES

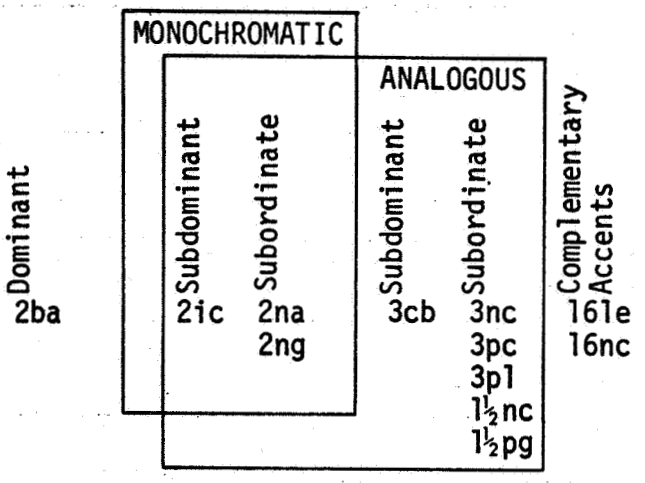


LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.75 to 1.0
Air Flow Rate: 60 fpm
Metabolic Rate: 400 Btu/hr
Occupancy Time: 2 hrs/day

EXAMPLE COLOR SCHEME

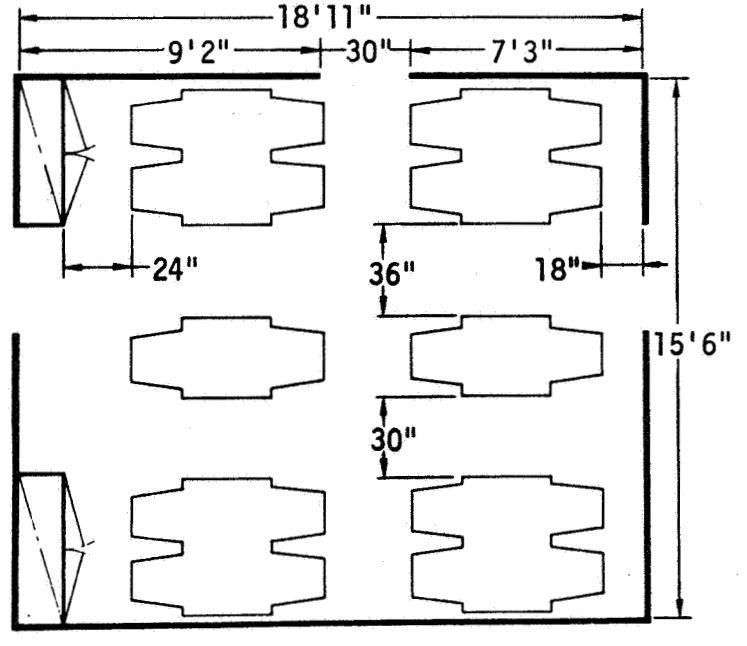
Color Effects: Cheering, relaxing



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Warm colors are used to enhance feelings of relaxation and aid the senses of taste and odor.

VOLUME

Remarks: The following recommendations are to be used for general guidance only; unless otherwise noted, the area recommendations pertain to an artificial gravity environment. Gross area/man = 15 ft^2. Ceiling height = 7'0" for up to 300 ft^2 gross area, 7'6" 300-500 ft^2 gross area. Seating provision recommendations are as follows: crews 6-20 = 100 percent of crew, for crews in excess of 20, seating should be provided for a minimum of 50 percent of the crew. More than two settings per meal should be avoided. This will likely be the largest visual area in the habitat.



2.2.2 Lounge.

Description: Mood: Restful
Activity: Low
Social Factor: Public

LIGHTING

Light Source: Incandescent and fluorescent

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	20-30	30-10

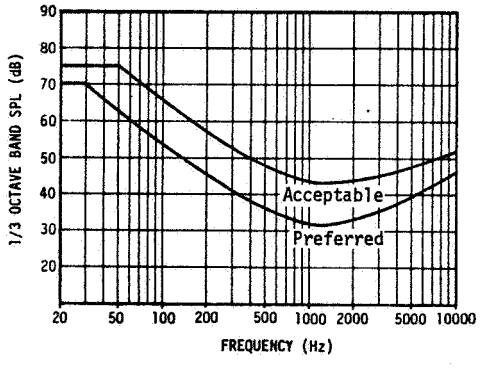
SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	60-90	90-60
Walls	35-60	60-30
Floors	15-35	35-10
Furniture	20-40	45-15
Draperies	15-60	60-15

Remarks: Lighting should be designed primarily for comfort and relaxation. Emphasis should be placed on creating variations within the room with 30 ft c in reading areas. Provide adequate visual rest centers. Friendly, warm sources desirable.

ACOUSTICS

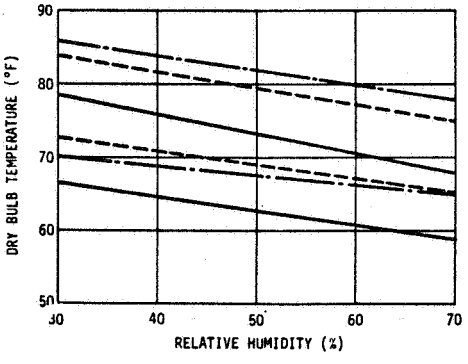
SOUND PRESSURE LEVEL



Remarks: Annoying noise sources (intermittent, high-pitched, unlocalized) must be avoided. Thick carpets, drapes, and padded cloth furniture help to trap noise.

TEMPERATURE

COMFORT ZONES

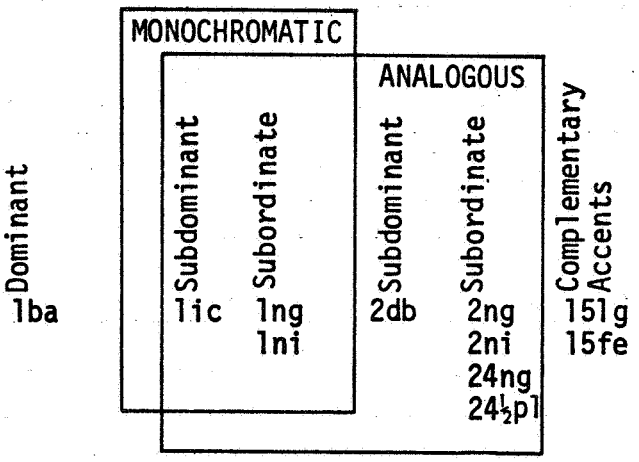


LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.75 to 1.0
Air Flow Rate: 50 fpm
Metabolic Rate: 450 Btu/hr
Occupancy Time: 2.5 hrs/day

EXAMPLE COLOR SCHEME

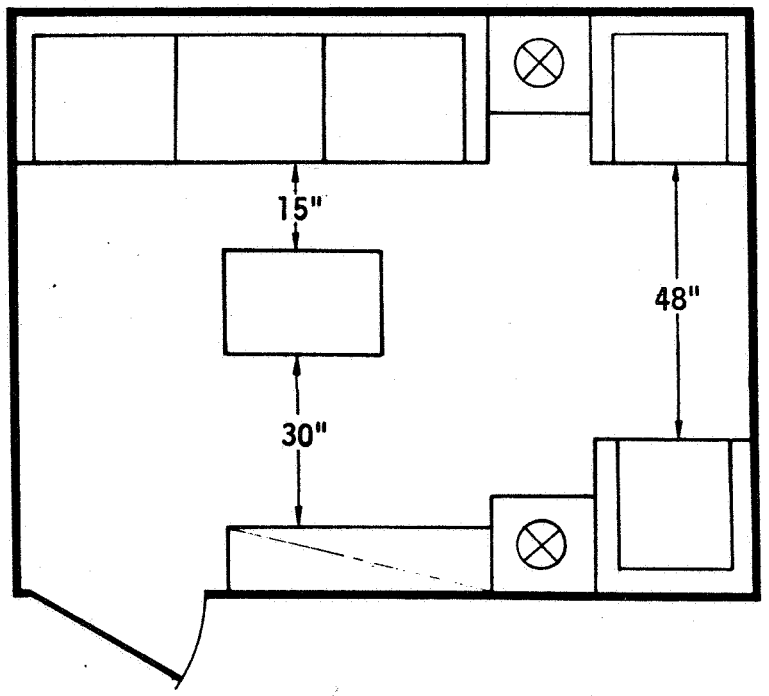
Color Effects: Cheering, relaxing



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only.
Warm colors with low intensities and subtle value changes supplement a relaxed attitude and add a note of cheerfulness.

VOLUME

Remarks: The following recommendations are to be used for general guidance only; unless otherwise noted, the area recommendations pertain to an artificial gravity environment. Provide lounge seats based on 20 percent of crew sizes from 6-50. Minimum 4 seats. For crew sizes from 50-100 provide lounge seats based on 15 percent of crew size over 50, plus 10. Gross area/seat = 16 ft^2. Ceiling height = 7'0".



2.2.3 Recreation.

Description: Mood: Mental concentration* and physical activity
Activity: Moderate to high
Social Factor: Public

LIGHTING

Light Source: Incandescent and fluorescent

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	20-30	30-10

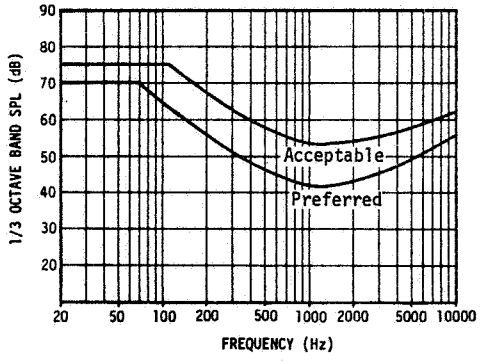
SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	60-90	90-60
Walls	40-60	70-35
Floors	15-35	50-15
Furniture	25-45	45-20
Draperies	15-60	60-15

Remarks: Lighting should be general to allow maximum use of area for active recreation. Colors should be cool. Individual game areas should be highlighted. Relaxing as in lounge.

ACOUSTICS

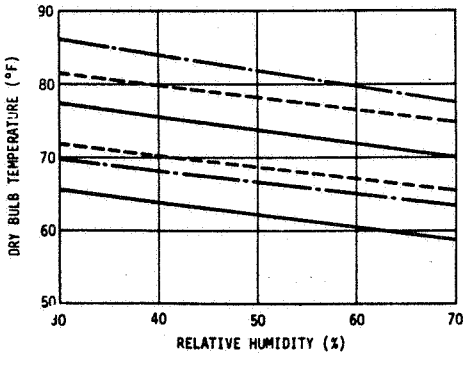
SOUND PRESSURE LEVEL



Remarks: SIL level below 60 dB must be maintained. From standpoint of noise control, ideal wall, ceiling, and floor should be massive with rough porous surface. Thick carpets, drapes, and padded cloth furniture help to trap noise.

TEMPERATURE

COMFORT ZONES



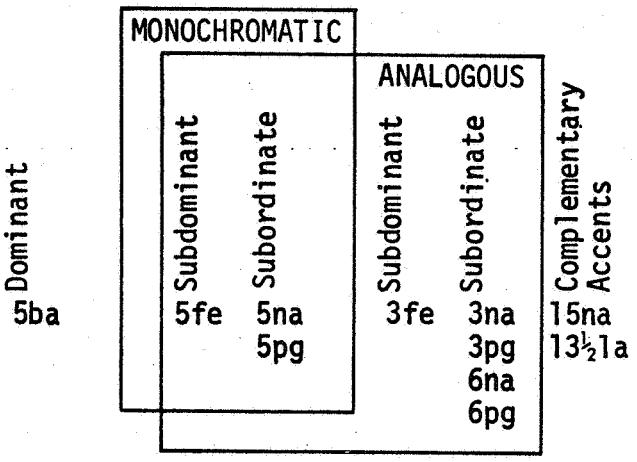
LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.75 to 1.0
Air Flow Rate: 70 fpm
Metabolic Rate: 450 to 700 Btu/hr
Occupancy Time: 2 hrs/day

*Card games

EXAMPLE COLOR SCHEME

Color Effects: Exciting, stimulating



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only.
Warm colors with high intensities enhance feelings of excitement and low responsibility.

VOLUME

Remarks: Gym, theater, dining area and crew compartment areas are utilized for recreation activities.

2.2.4 Library.

Description: Mood: Restful and mental concentration
Activity: Low
Social Factor: Public

LIGHTING

Light Source: Incandescent-halogen cycle, fluorescent

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	20-30	30-10

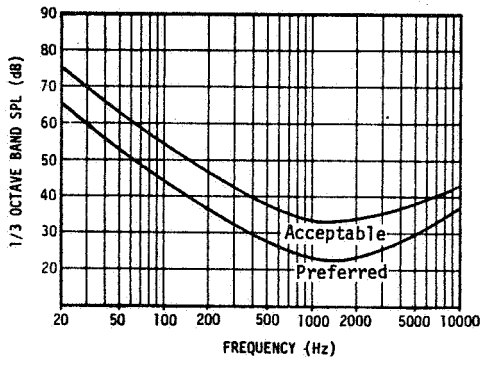
Remarks: Lighting should be suitable for reading, either at a table or in a chair. Relaxing.

SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	60-90	90-60
Walls	40-70	70-35
Floors	15-35	40-10
Furniture	35-50	50-20
Draperies	15-60	60-15

ACOUSTICS

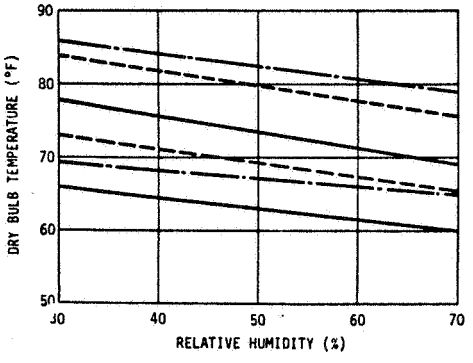
SOUND PRESSURE LEVEL



Remarks: SIL levels below 50 dB must be maintained. Intermittent and high-pitched noise sources must be avoided to promote restful atmosphere and facilitate mental concentration. Thick carpets, drapes, and padded cloth furniture help to trap noise.

TEMPERATURE

COMFORT ZONES

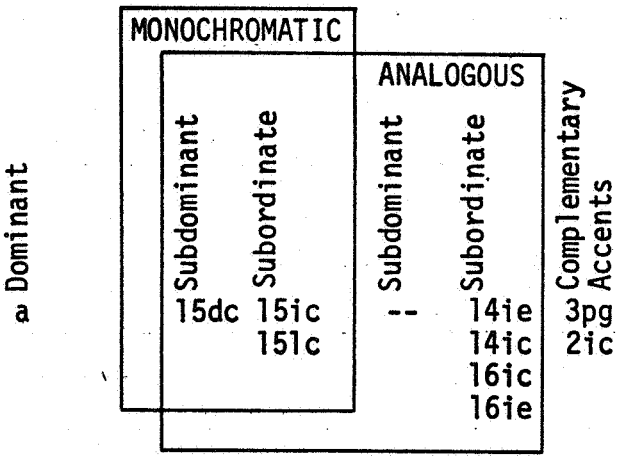


LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.75 to 1.0
Air Flow Rate: 50 fpm
Metabolic Rate: 450 Btu/hr
Occupancy Time: 1 hr/day

EXAMPLE COLOR SCHEME

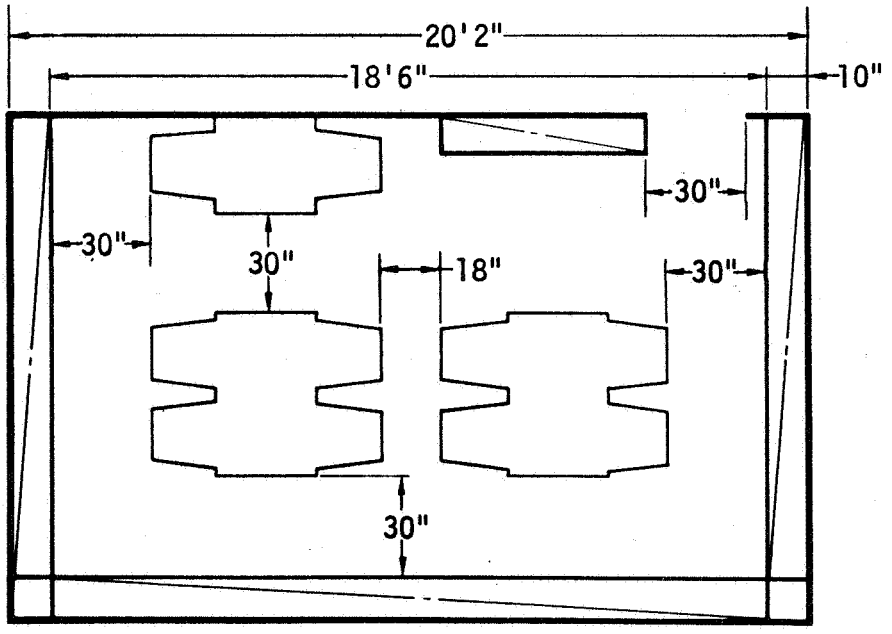
Color Effects: Neutralizing, relaxing, subduing



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Colors provide adequate illumination levels for sight tasks and cool hues evoke an atmosphere of relaxed restraint and high responsibility.

VOLUME

Remarks: The following recommendations are to be used for general guidance only; unless otherwise noted, the area recommendations pertain to an artificial gravity environment. Mission 30-60 days = 0.5 linear ft of shelves/man; 60-120 = 1.0'/man; 120-1040 = 2.0'/man. Minimum books/mission = mission duration (days). One linear ft of wall space = 6 linear ft of shelf space. One linear ft of shelf space = 7 books. Linear ft of books = approximately one square of gross area required for library. Ceiling height = 7'0". Key passageway dimensions shown in schematic layout.



2.2.5 Study.

Description: Mood: Restful and mental concentration
Activity: Low
Social Factor: Public

LIGHTING

Light Source: Incandescent-halogen cycle, fluorescent

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	20-30	30-10

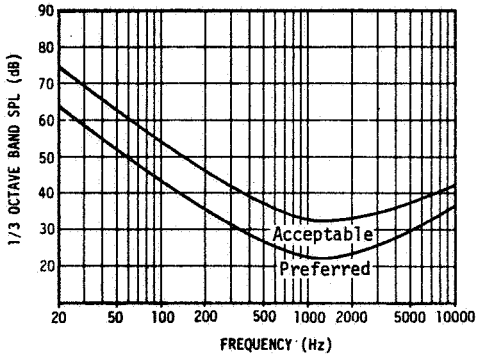
Remarks: Lighting should be suitable for reading, either at a table or in a chair. Relaxing.

SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	60-90	90-60
Walls	40-70	70-35
Floors	15-35	40-10
Furniture	35-50	50-20
Draperies	15-60	60-15

ACOUSTICS

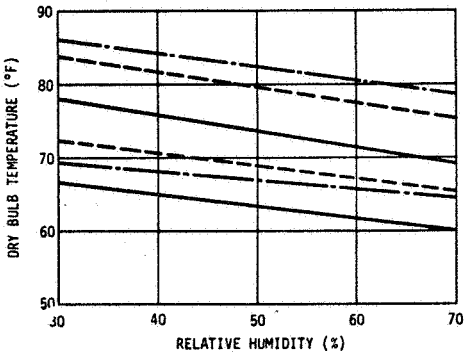
SOUND PRESSURE LEVEL



Remarks: SIL levels below 50 dB must be maintained. Intermittent and high-pitched noise sources must be avoided to promote restful atmosphere and facilitate mental concentration. Thick carpets, drapes, and padded cloth furniture help to trap noise.

TEMPERATURE

COMFORT ZONES

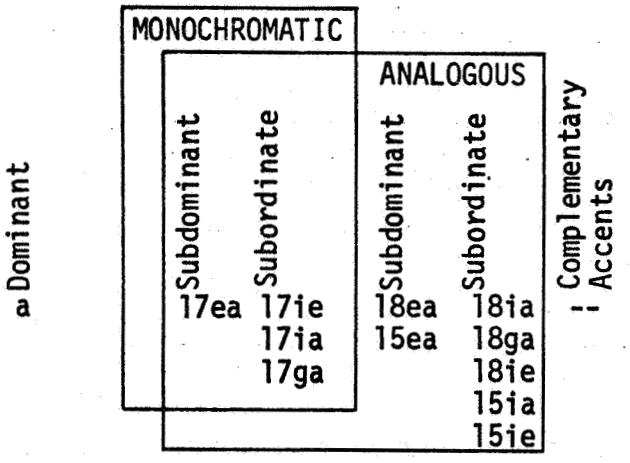


LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.75 to 1.0
Air Flow Rate: 50 fpm
Metabolic Rate: 450 Btu/hr
Occupancy Time: 1 hr/day

EXAMPLE COLOR SCHEME

Color Effects: Neutralizing, retiring



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only.
Colors provide adequate illumination for sight tasks, and cool hues evoke an atmosphere of relaxed restraint and high responsibility.

VOLUME

Remarks: Not independent area. Provisions for study exist in crew compartment and library.

2.2.6 Conference.

Description: Mood: Mental concentration
Activity: Moderate to low
Social Factor: Public

LIGHTING

Light Source: Fluorescent and metal halide

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	50-70	70-20

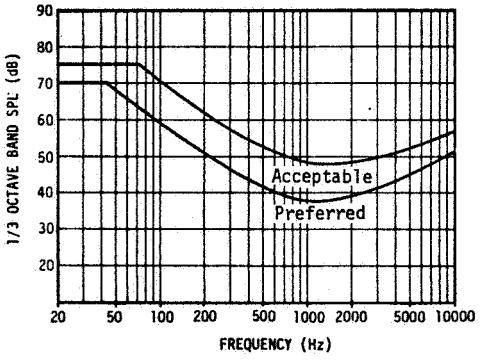
Remarks: Lighting should be efficient and functional. Colors should be cool but stimulating.

SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	60-90	90-60
Walls	40-60	60-40
Floors	15-35	35-15
Furniture	20-45	45-20
Machines	25-45	45-20

ACOUSTICS

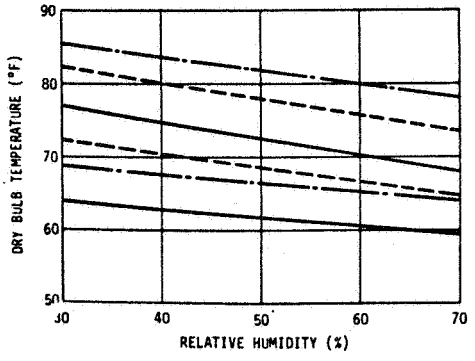
SOUND PRESSURE LEVEL



Remarks: SIL levels below 60 dB must be maintained to promote face-to-face communication. Avoid intermittent, high-pitched and unlocalized noise sources. Thick carpets, drapes, and padded cloth furniture can be used to help trap noise.

TEMPERATURE

COMFORT ZONES

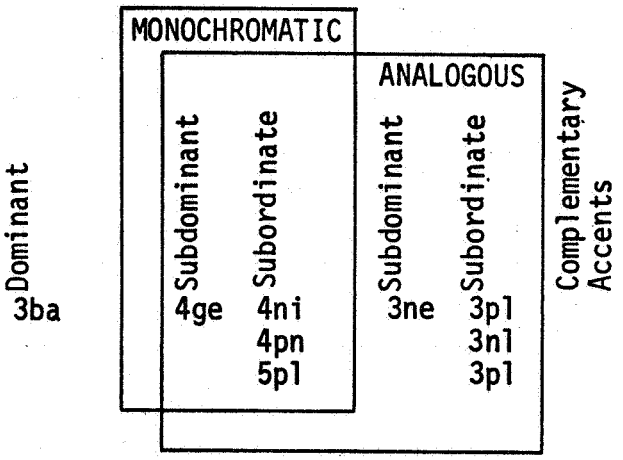


LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.75 to 1.0
Air Flow Rate: 60 fpm
Metabolic Rate: 500 Btu/hr
Occupancy Time: 2 hrs/day

EXAMPLE COLOR SCHEME

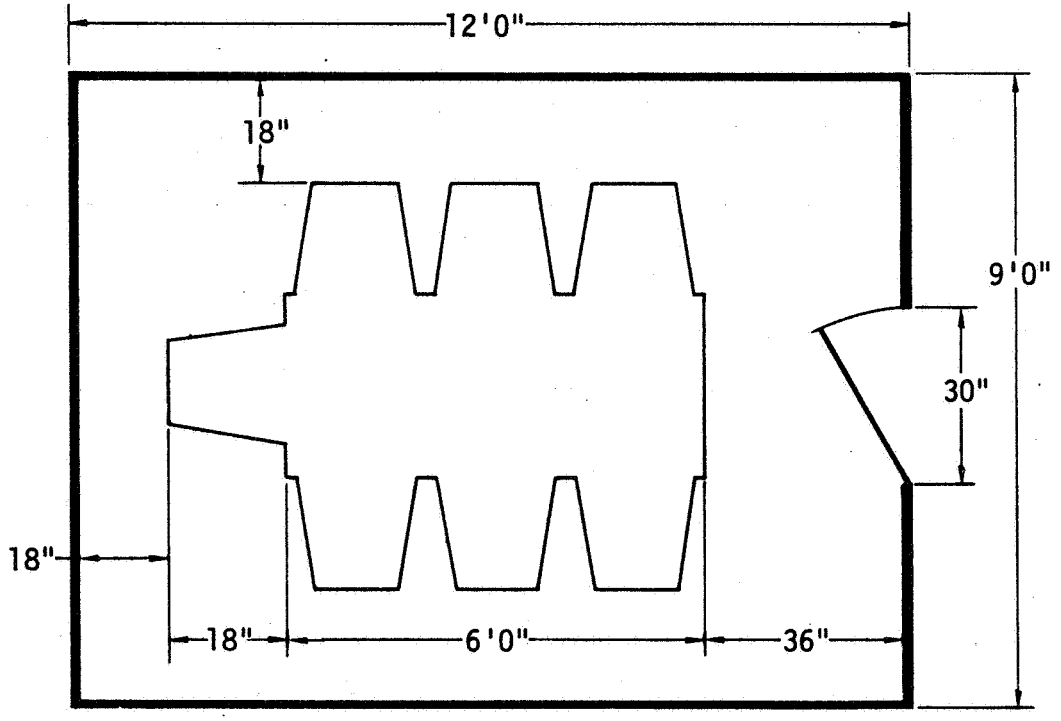
Color Effect: Stimulating



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Warm colors add to stimulating atmosphere which lends itself to discussion and the exchange of points of view.

VOLUME

Remarks: The following recommendations are to be used for general guidance only; unless otherwise noted, the area recommendations pertain to an artificial gravity environment. Sufficient seating should be provided for the commander and 100 percent of department heads plus two seats. Interior dimensions shown represent acceptable minimum passageway clearances. Gross area/man = 15 ft^2. Ceiling height = 7'0".



2.2.7 Passageway.

Description: Mood: Physical activity
Activity: Moderate
Social Factor: Public

LIGHTING

Light Source: Incandescent-halogen cycle

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	5-20	20-1

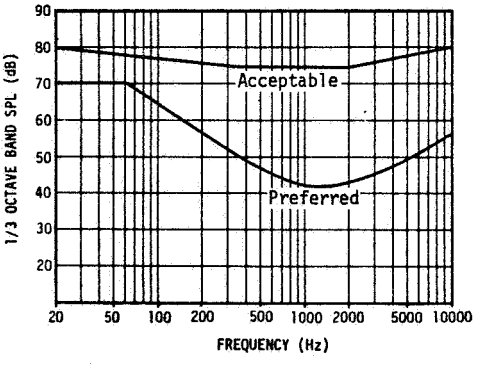
SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	40-80	90-40
Walls	20-45	50-20
Floors	15-35	50-15

Remarks: Lighting generally should be adequate to observe any obstacles. Hallways provide transition between lighted areas; consequently, lighting and color should meet transition function. Lighting level should be no greater than 1/5th of adjacent areas.

ACOUSTICS

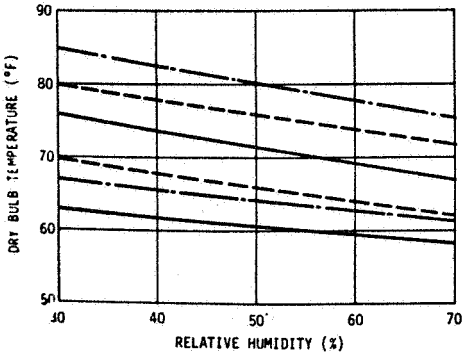
SOUND PRESSURE LEVEL



Remarks: SIL levels below 70 dB should be maintained so as not to interfere with loudspeaker communication. Floors made of bare woods magnify impact noises, particularly in long corridors. Carpet with proper padding will absorb airborne sounds.

TEMPERATURE

COMFORT ZONES

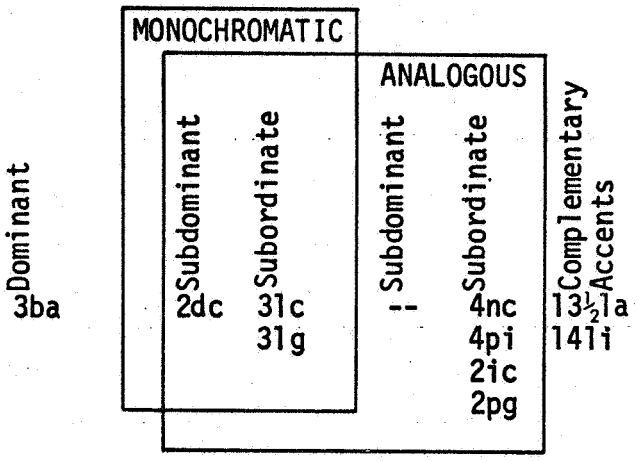


LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.75 to 1.2
Air Flow Rate: 60 fpm
Metabolic Rate: 400 to 750 Btu/hr
Occupancy Time: 0.5 hr/day

EXAMPLE COLOR SCHEME

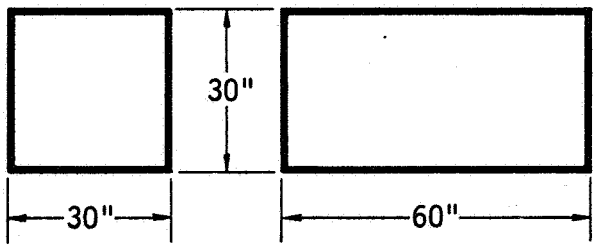
Color Effect: Neutralizing



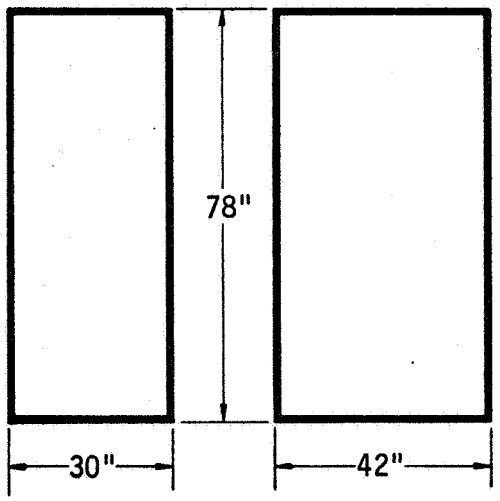
Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only.
Neutral scheme creates an expansiveness in narrow areas and allows for good transition into areas which will be of different color schemes.

VOLUME

Remarks: The following recommendations are to be used for general guidance only; unless otherwise noted, the area recommendations pertain to an artificial gravity environment. Zero-gravity passageway volume based on limited data.



Zero Gravity



Artificial Gravity

2.2.8 Chapel.

Description: Mood: Restful and spiritual concentration
Activity: Low
Social Factor: Public

LIGHTING

Light Source: Incandescent-halogen cycle

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	5-20	20-2

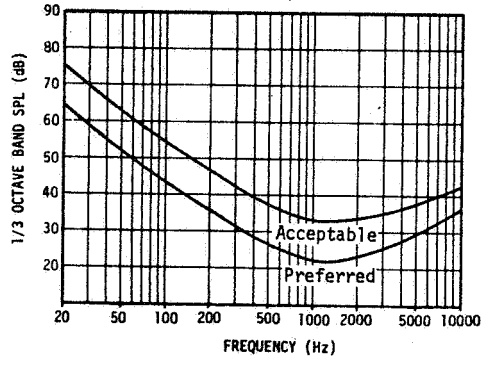
SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	50-80	85-50
Walls	20-50	50-20
Floors	15-35	35-10
Furniture	15-40	40-10

Remarks: Lower subdued atmosphere for meditation; higher lighting levels for active worship. Specific highlighting of alter for focus of attention. Colors subdued.

ACOUSTICS

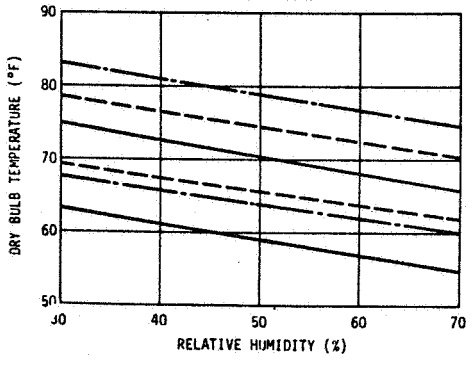
SOUND PRESSURE LEVEL



Remarks: SIL levels below 50 dB must be maintained. Intermittent and high-pitched noise sources must be avoided to promote restful atmosphere and facilitate mental concentration. Thick carpets, drapes, and padded cloth furniture help to trap noise.

TEMPERATURE

COMFORT ZONES

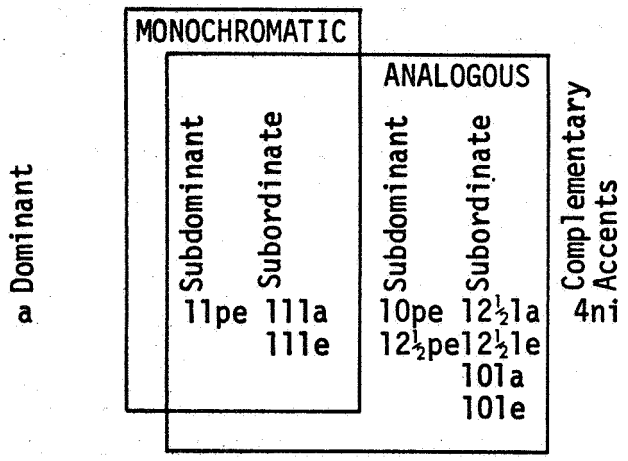


LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.75 to 1.0
Air Flow Rate: 60 fpm
Metabolic Rate: 400 Btu/hr
Occupancy Time: 1 hr/day

EXAMPLE COLOR SCHEME

Color Effects: Retiring, relaxing, subduing



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only.
Colors used are those associated with religious significance.

VOLUME

Remarks: See Theater.

2.2.9 Gym.

Description: Mood: Physical Activity
Activity: High
Social Factor: Public

LIGHTING

Light Source: Fluorescent, mercury vapor, metal halide

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	20-30	30-15

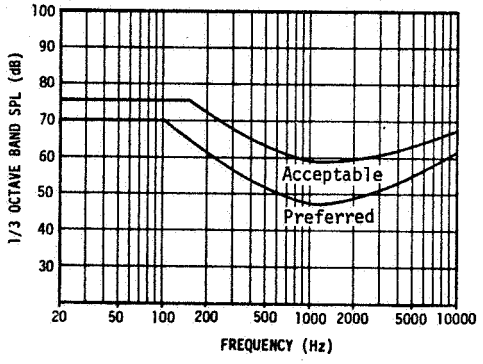
Remarks: General lighting for maximum use of area. Cool colors.

SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	70-90	90-60
Walls	40-60	70-35
Floors	15-35	35-15

ACOUSTICS

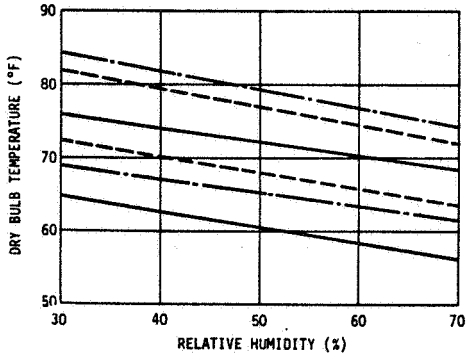
SOUND PRESSURE LEVEL



Remarks: None

TEMPERATURE

COMFORT ZONES



LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.5 to 1.3
Air Flow Rate: 80 fpm
Metabolic Rate: 750 to 1800 Btu/hr
Occupancy Time: 1.5 hrs/day

EXAMPLE COLOR SCHEME

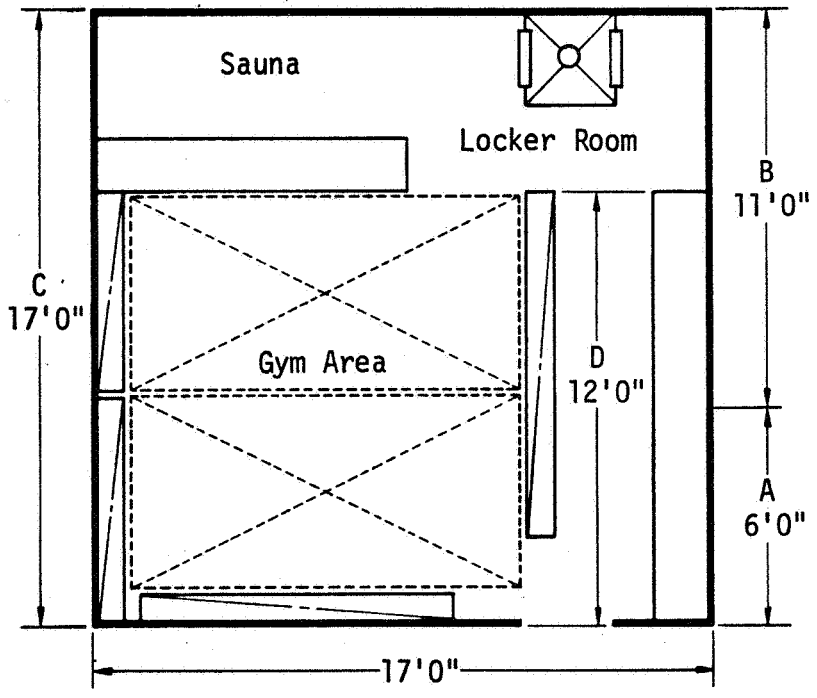
Color Effects: Exciting, stimulating

Dominant	MONOCHROMATIC		ANALOGOUS		Complementary Accents
	Subdominant	Subordinate	Subdominant	Subordinate	
5ba	5fe	5ng 5pe	3fe	3ng 3pe 3ia 3ea	17ic 15lc

Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Feelings of excitement and stimulation are accented by warm hues.

VOLUME

Remarks: The following recommendations are to be used for general guidance only; unless otherwise noted, the area recommendations pertain to an artificial gravity environment.
A- size for crews of 6-50 men on missions of 30-180 days 102 ft^2 gross
B- size for crews of 6-50 men on missions of 180-1040 days 187 ft^2 gross
C- size for crews of 50-100 men on missions of 180-1040 days 289 ft^2 gross
D- size for crews of 50-100 men on missions of 30-180 days 204 ft^2 gross
Ceiling Height = 7'0".



2.2.10 Locker Room.

Description: Mood: Physical activity
Activity: Moderate
Social Factor: Public

LIGHTING

Light Source: Fluorescent

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	20-30	30-10

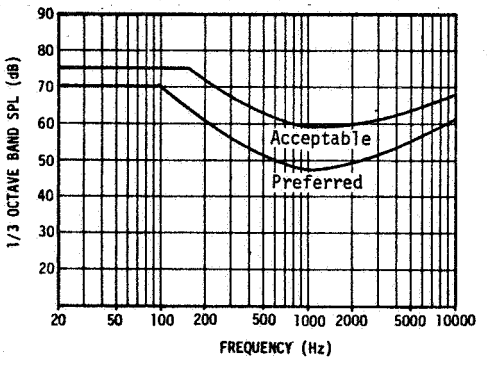
Remarks: General lighting for maximum use of area. Cool colors.

SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	60-90	90-60
Walls	20-50	50-20
Floors	15-35	35-15

ACOUSTICS

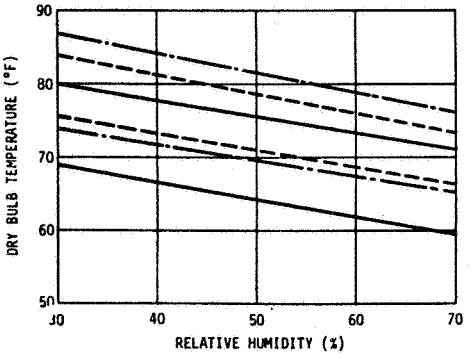
SOUND PRESSURE LEVEL



Remarks: None

TEMPERATURE

COMFORT ZONES

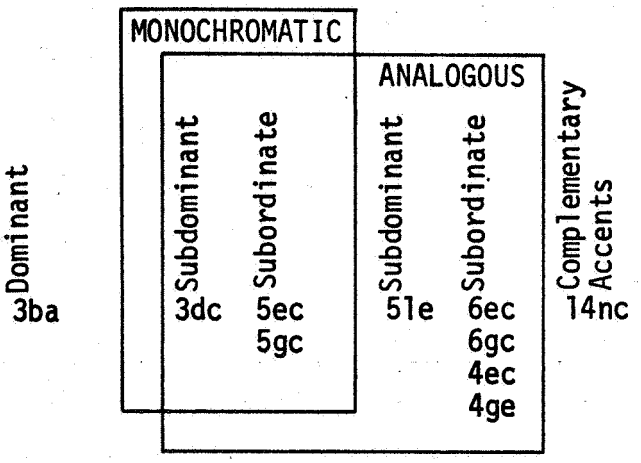


LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0 to 1.3
Air Flow Rate: 70 fpm
Metabolic Rate: 600 Btu/hr
Occupancy Time: 0.75 hr/day

EXAMPLE COLOR SCHEME

Color Effect: Cheering



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only.
Colors should be of warm hues which enhance skin tones.

VOLUME

Remarks: See gym.

2.2.11 Theater.

Description: Mood: Restful
Activity: Low
Social Factor: Public

LIGHTING

Light Source: Incandescent and fluorescent

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	5-20	25-2

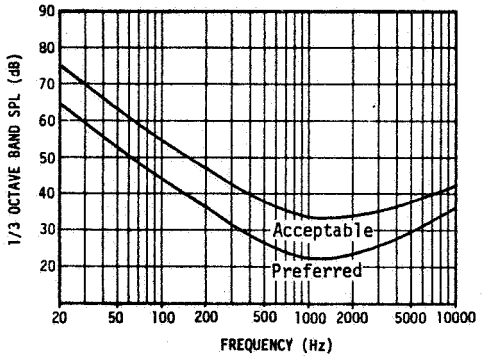
SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	60-90	90-60
Walls	35-60	60-30
Floors	15-35	35-10
Furniture	20-40	45-15
Draperies	15-60	60-15

Remarks: General lighting controllable from high to off to meet needs of film projection. Very low intensity lighting as required to maintain safety when general lighting is off. Relaxing colors.

ACOUSTICS

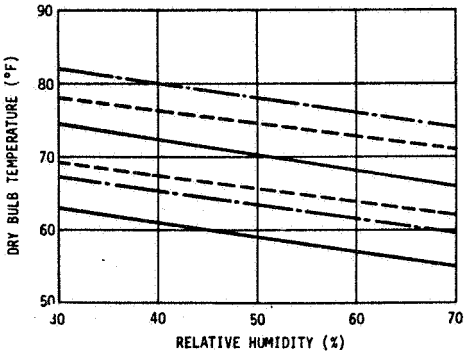
SOUND PRESSURE LEVEL



Remarks: None

TEMPERATURE

COMFORT ZONES

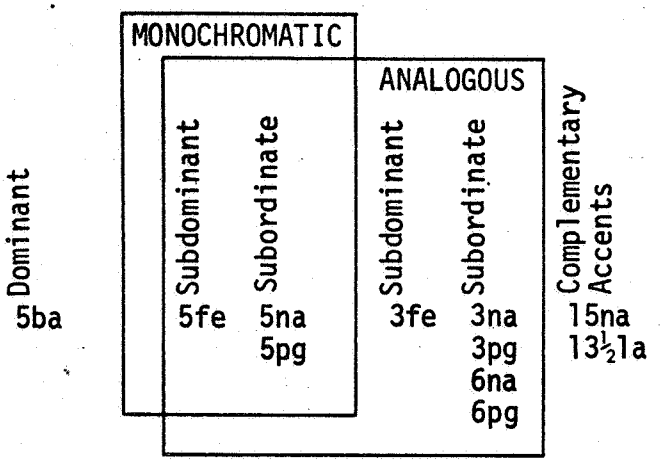


LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.75 to 1.0
Air Flow Rate: 60 fpm
Metabolic Rate: 450 Btu/hr
Occupancy Time: 2 hrs/day

EXAMPLE COLOR SCHEME

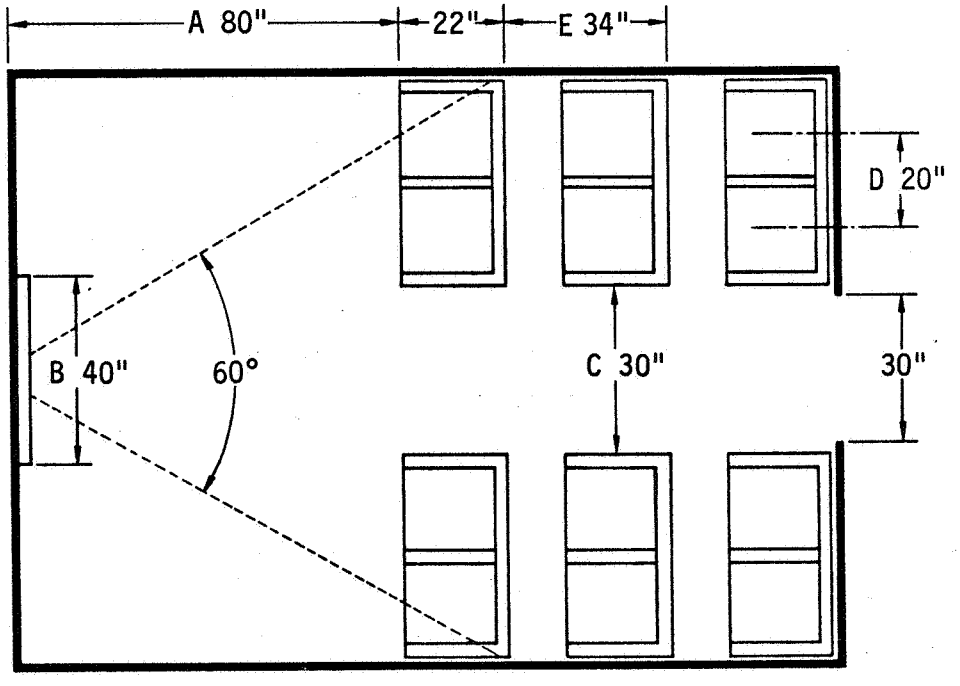
Color Effect: Stimulating



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only.
Warm colors with high intensities enhance feelings of excitement and low responsibility.

VOLUME

Remarks: The following recommendations are to be used for general guidance only; unless otherwise noted, the area recommendations pertain to an artificial gravity environment. Sufficient seating should be provided for 50 percent of the crew. Gross area/man = 10-12 ft^2. Ceiling Height: 7'0" = 100-300 ft^2, 7'6" = 300-500 ft^2. Key dimensions shown are: A- Minimum viewing distance; B- Minimum screen size; C- Major through-passage; D- Seats (center-to-center); E- Seats (back-to-back).



2.2.12 Briefing Room.

Description: Mood: Mental concentration
Activity: Moderate
Social Factor: Public

LIGHTING

Light Source: Fluorescent and metal halide

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	50-70	70-20

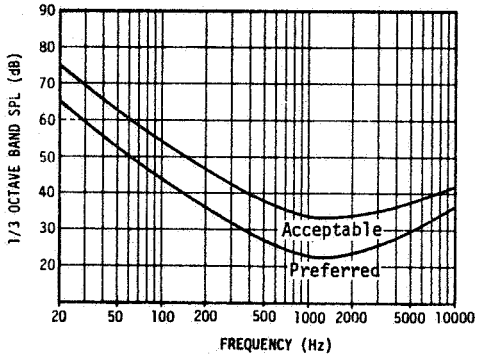
SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	60-90	90-60
Walls	50-70	70-50
Floors	15-35	35-15
Furniture	25-45	45-15

Remarks: Lighting should be efficient and functional with emphasis in some areas. Projection type lighting may be required.

ACOUSTICS

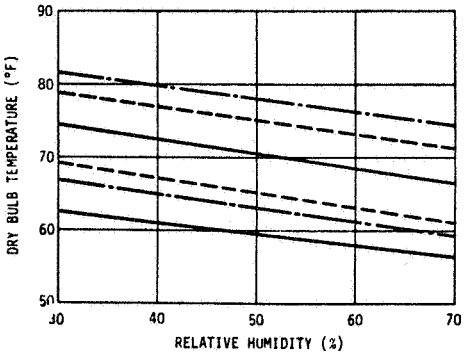
SOUND PRESSURE LEVEL



Remarks: SIL levels below 40 dB must be maintained to promote effective communication. Avoid intermittent high-pitched and unlocalized noise sources. Thick carpets, drapes, and padded cloth furniture can be used to help trap noise.

TEMPERATURE

COMFORT ZONES

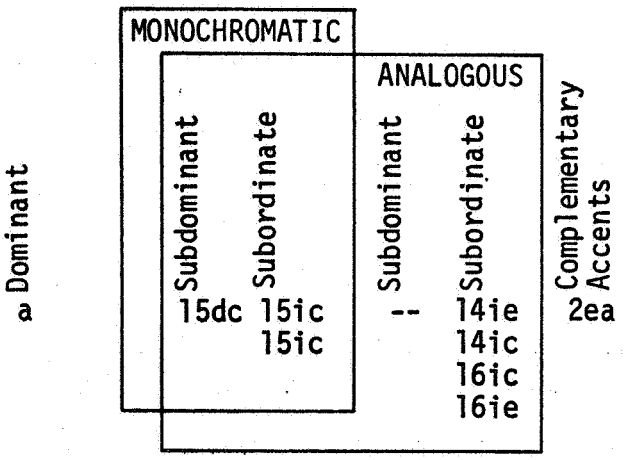


LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.75 to 1.0
Air Flow Rate: 60 fpm
Metabolic Rate: 500 Btu/hr
Occupancy Time: 1 hr/day

EXAMPLE COLOR SCHEME

Color Effect: Stimulating



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only.
Cool colors recommended with low contrast and intensity to cause the least amount of distraction.

VOLUME

Remarks: See conference room.

2.3 SERVICE AREAS

2.3.1 Galley.

Description: Mood: Physical activity
Activity: Moderate
Social Factor: Public

LIGHTING

Light Source: Incandescent-halogen cycle, fluorescent

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	20-50	50-10

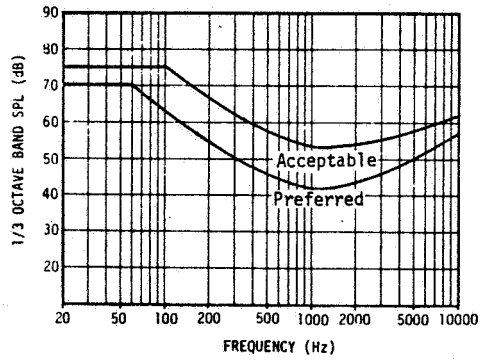
SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	70-90	90-60
Walls	40-70	70-35
Floors	20-40	40-20
Furniture	60-80	95-50

Remarks: For maintenance purposes area must be clean and bright. Lighting should be crisp and efficient with emphasis over work areas. Light surfaces will facilitate utilization of light in reaching cupboards, under counters, etc. Localized lighting over dish washing area for high degree of performance in inspecting clean dishes. Serving area should have deluxe color lamps to enhance appearance of food. Source equipment must be easily maintained and cleaned with minimum of dirt holding crevices or attachments.

ACOUSTICS

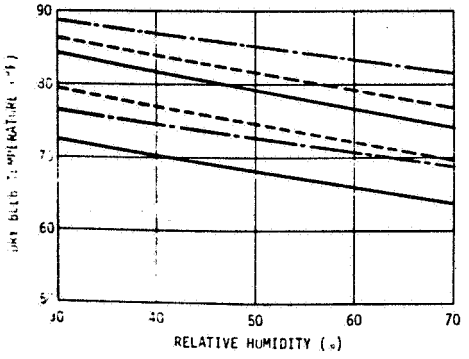
SOUND PRESSURE LEVEL



Remarks: High-pitched noise sources interfere most with work. Continuous high-pitched noise levels above 90 dB must be avoided.

TEMPERATURE

COMFORT ZONES

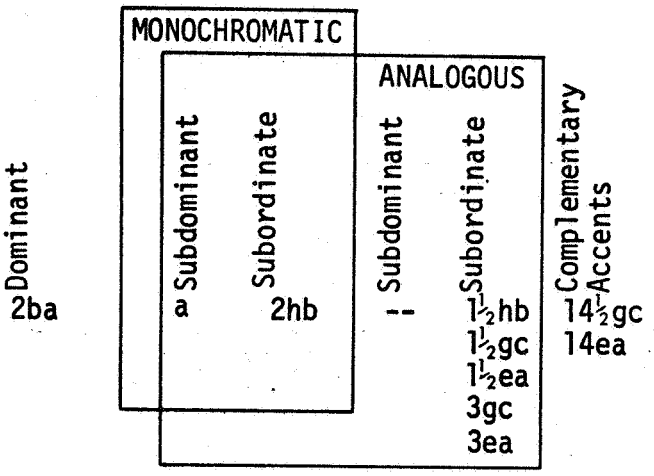


LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 1.0
Air Flow Rate: 80 fpm
Metabolic Rate: 700 Btu/hr
Occupancy Time: 1.5 hrs/day

EXAMPLE COLOR SCHEME

Color Effect: Cheering



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only.
A feeling of cheer is created with warm colors while maintaining high light levels.

VOLUME

Remarks: Area requirement of activity is mission equipment dependent.

2.3.2 Snack Bar.

Description: Mood: Restful
Activity: Moderate
Social Factor: Public

LIGHTING

Light Source: Incandescent-halogen cycle, fluorescent

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	10-30	30-10

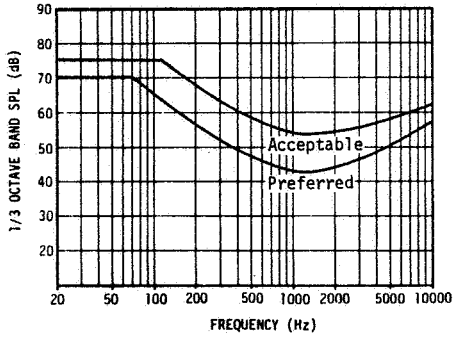
SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	60-90	90-60
Walls	35-60	60-35
Floors	15-35	35-15
Furniture	15-45	45-15
Draperies	15-60	60-15

Remarks: Lighting should be festive and engaging. Color should be flattering and relaxing. Higher levels for maintenance and movement of people.

ACOUSTICS

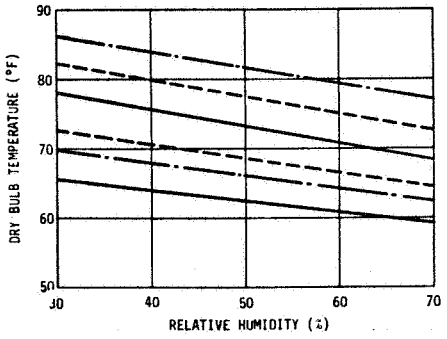
SOUND PRESSURE LEVEL



Remarks: High-pitched noise sources must be avoided to preclude crew annoyance. Unlocalized noise sources are more annoying than noise sources that can be localized. From standpoint of noise control, ideal wall, ceiling, and floor should be massive and porous. SIL levels below 60 dB should be maintained.

TEMPERATURE

COMFORT ZONES

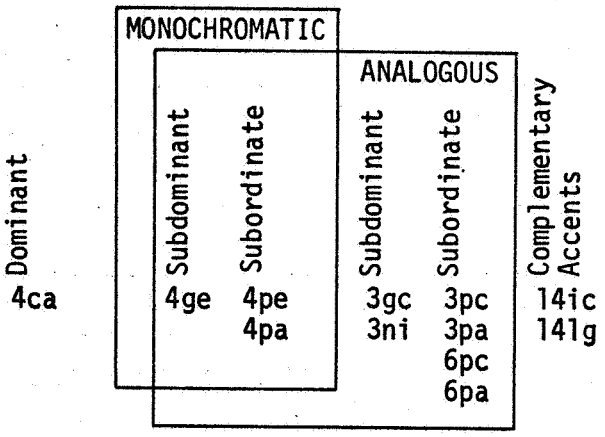


LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.75 to 1.0
Air Flow Rate: 70 fpm
Metabolic Rate: 500 Btu/hr
Occupancy Time: 1 hr/day

EXAMPLE COLOR SCHEME

Color Effect: Cheering



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only.

VOLUME

Remarks: Not an independent area; utilizes dining facilities, food and beverage dispensers, and dining tables during non-meal hours.

2.3.3 Bathroom.

Description: Mood: Restful
Activity: Low
Social Factor: Very private

LIGHTING

Light Source: Incandescent-Halogen cycle, fluorescent

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	10-30	30-5

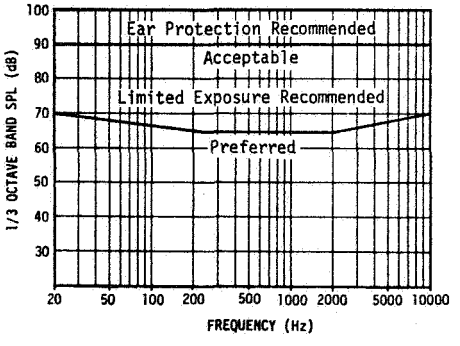
SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	60-90	90-60
Walls	40-70	70-35
Floors	20-40	40-20
Furniture	60-90	99-60

Remarks: Definite use of deluxe colors for flattering appraisal of complexion and skin tones. Light specifically over lavatory area to provide adequate illumination for cleaning and shaving functions. Care should be taken to insure light reaching underside of chin. Lower lighting levels sufficient in other bathroom areas.

ACOUSTICS

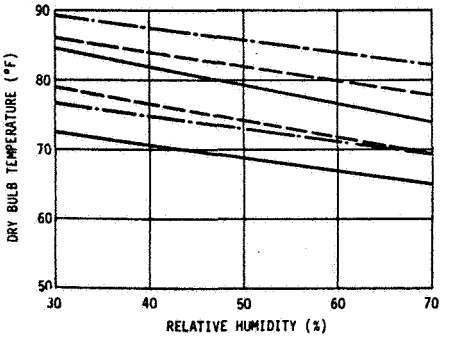
SOUND PRESSURE LEVEL



Remarks: Annoying noise sources (intermittent, high-pitched, unlocalized) must be avoided.

TEMPERATURE

COMFORT ZONES

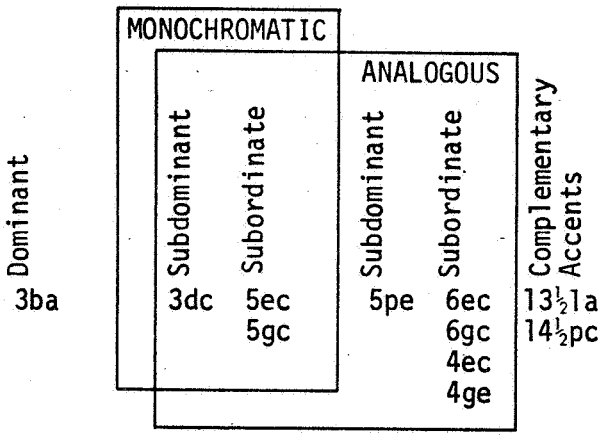


LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0 to 1.0
Air Flow Rate: 40 to 80 fpm
Metabolic Rate: 500 Btu/hr
Occupancy Time: 0.5 hr/day

EXAMPLE COLOR SCHEME

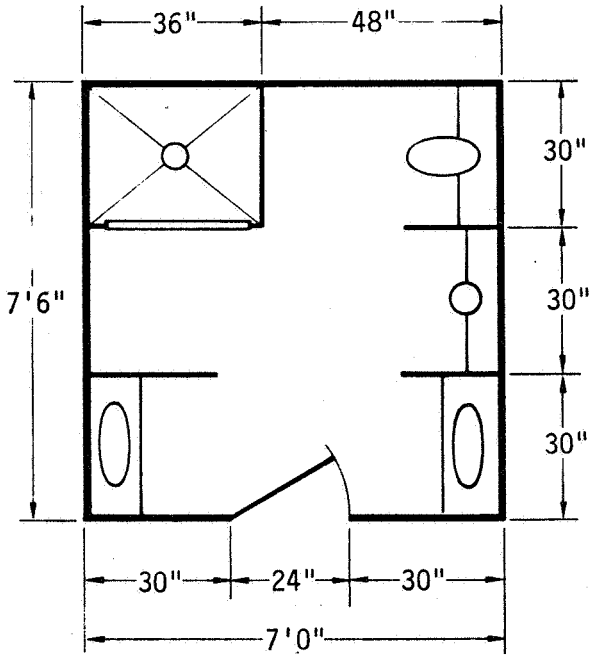
Color Effects: Stimulating, cheering, neutralizing, relaxing

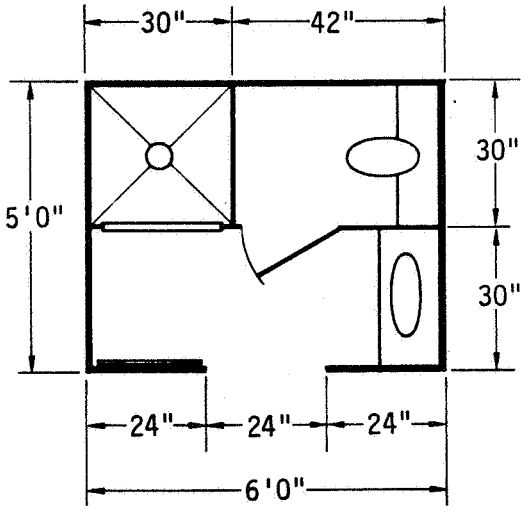


Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only.
Warm hues used enhance skin tones to generate feelings of health and well-being.

VOLUME

Remarks: The following recommendations are to be used for general guidance only; unless otherwise noted, the area recommendations pertain to an artificial gravity environment. The example layouts shown were developed from size and clearance figures presented in Section 3.5 and fixture requirement recommendations presented in Section 4.2.
Ceiling Height = 6'6".





2.3.4 Dispensary.

Descripriton: Mood: Restful
Activity: Low
Social Factor: Public

LIGHTING

Light Source: Incandescent-halogen cycle, fluorescent

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	50-100	100-30

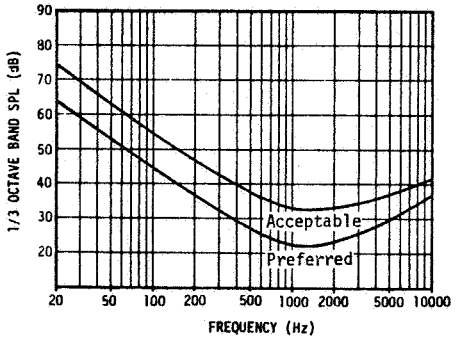
SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	70-90	90-60
Walls	50-70	80-50
Floors	20-40	40-15
Furniture	45-80	85-35

Remarks: Atmosphere should be clean and sterile. Localized examination lights should be color-corrected and provide proper amounts of light on specific areas being studied. Provisions should be made for providing 50-100 ft c for short duration operations and other emergency practices. Deluxe color general lighting essential.

ACOUSTICS

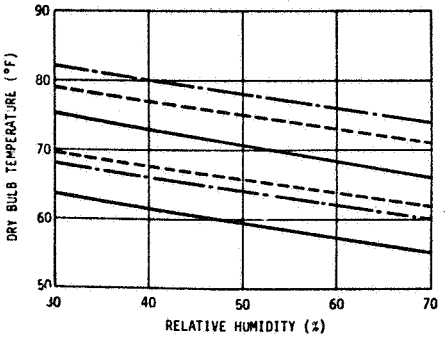
SOUND PRESSURE LEVEL



Remarks: SIL levels should be maintained below 50 dB. Annoying noise sources (intermittent, high-pitched, unlocalized) should be especially avoided.

TEMPERATURE

COMFORT ZONES

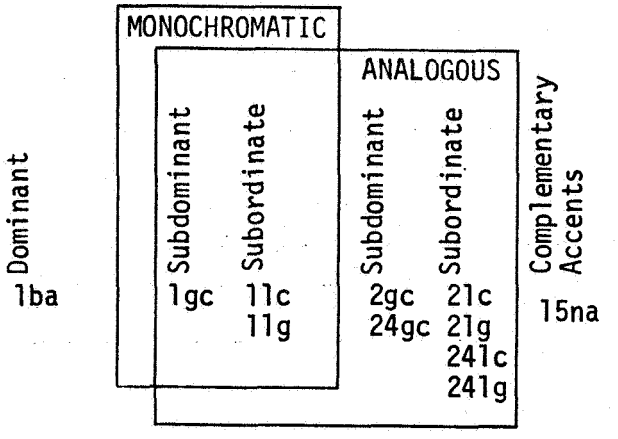


LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0 to 1.0
Air Flow Rate: 60 fpm
Metabolic Rate: 600 Btu/hr
Occupancy Time: 2 hrs/day

EXAMPLE COLOR SCHEME

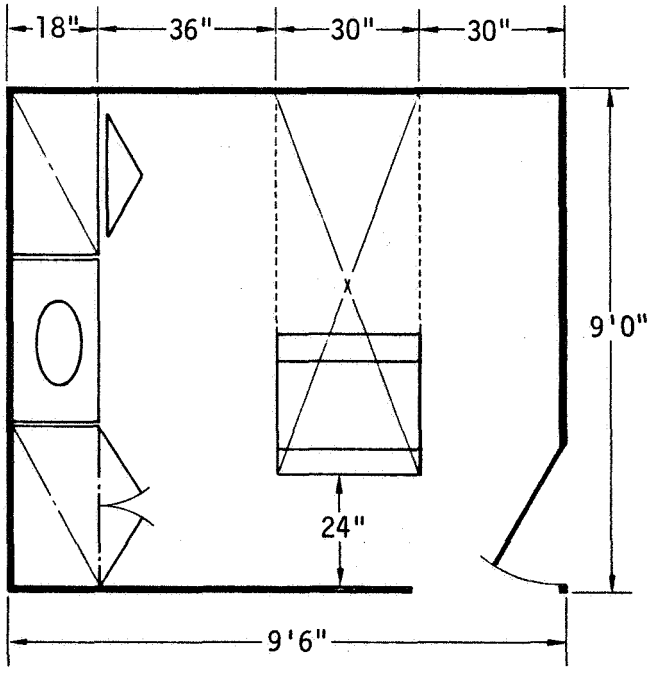
Color Effects: Cheering, relaxing



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only.
Colors are those generally accepted in hospitals which tend to sublimate feelings of depression.

VOLUME

Remarks: The following recommendations are to be used for general guidance only; unless otherwise noted, the area recommendations pertain to an artificial gravity environment. For missions which require a dispensary, direct access should be provided to a bathroom and medical records, file or office. To make maximum utilization of the area, it may be possible to have its function as a barbershop since the physical layout and net-space requirements are similar and the frequency of usage for both would probably be low. Ceiling height is 6'6". Gross Area = 85.5 ft^2.



2.3.5 Laundry.

Description: Mood: Physical Activity
Activity: Moderate to high
Social Factor: Public

LIGHTING

Light Source: Incandescent-Halogen cycle, fluorescent, mercury vapor

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	20-30	30-15

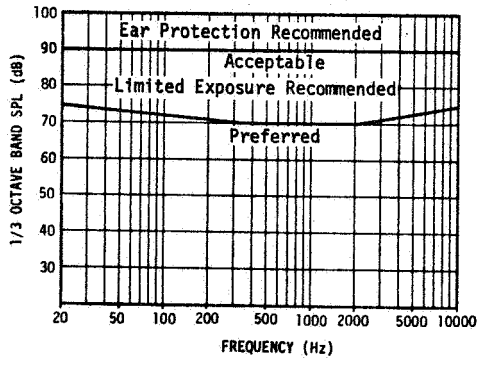
SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	60-90	90-60
Walls	40-65	70-35
Floors	15-35	35-15
Furniture	60-80	90-50

Remarks: General lighting should be uniform and adequate for the tasks. Inspection or mending area should be provided with higher level for work performance.

ACOUSTICS

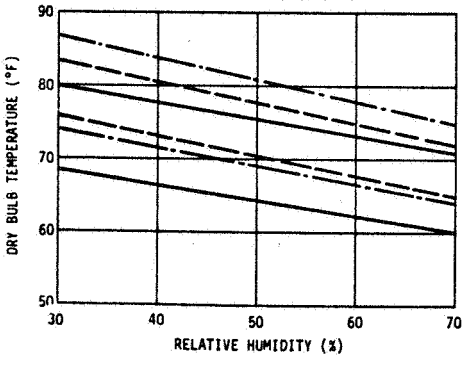
SOUND PRESSURE LEVEL



Remarks: None

TEMPERATURE

COMFORT ZONES



LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.75 to 1.0
Air Flow Rate: 80 fpm
Metabolic Rate: 1000 Btu/hr
Occupancy Time: 0.5 hr/day

EXAMPLE COLOR SCHEME

Color Effects: Neutralizing

Dominant	MONOCHROMATIC		ANALOGOUS		Complementary Accents
	Subdominant	Subordinate	Subdominant	Subordinate	
a	15dc	15ic	--	14ie	3pg
		15ie		14ic	2ic
				16ic	
				16ie	

Remarks: The example shown here is an acceptable color scheme for this activity mood; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only.
Adequate lighting is provided for sight tasks. Basic cool hues are conducive to feelings of spaciousness, responsibility, and tend to make time pass more rapidly. Low color intensity and value contrasts serve to complement attentiveness.

VOLUME

Remarks: Area requirement of activity is mission equipment dependent.

2.3.6 Barbershop.

Description: Mood: Restful
Activity: Moderate to low
Social Factor: Public

LIGHTING

Light Source: Fluorescent-deluxe colors

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	20-30	30-15

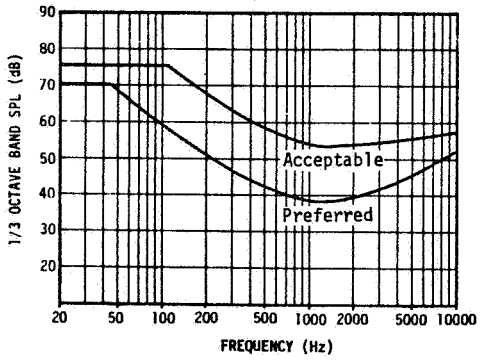
Remarks: Deluxe color lamps over barber chair positioned for adequate observation and work.

SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	70-90	90-60
Walls	50-70	80-50
Floors	20-40	40-15
Furniture	30-60	80-30

ACOUSTICS

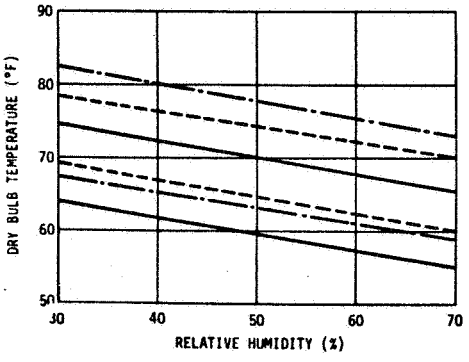
SOUND PRESSURE LEVEL



Remarks: High-pitched noise sources must be avoided to preclude crew annoyance. Unlocalized noise sources are more annoying than noise sources that can be localized. From standpoint of noise control, ideal wall, ceiling, and floor should be massive and porous. SIL levels below 60 dB should be maintained.

TEMPERATURE

COMFORT ZONES

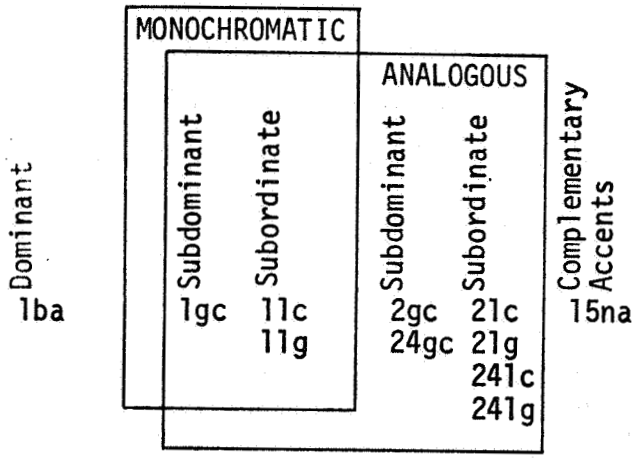


LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.75 to 1.0
Air Flow Rate: 60 fpm
Metabolic Rate: 600 Btu/hr
Occupancy Time: 0.5 hr/day

EXAMPLE COLOR SCHEME

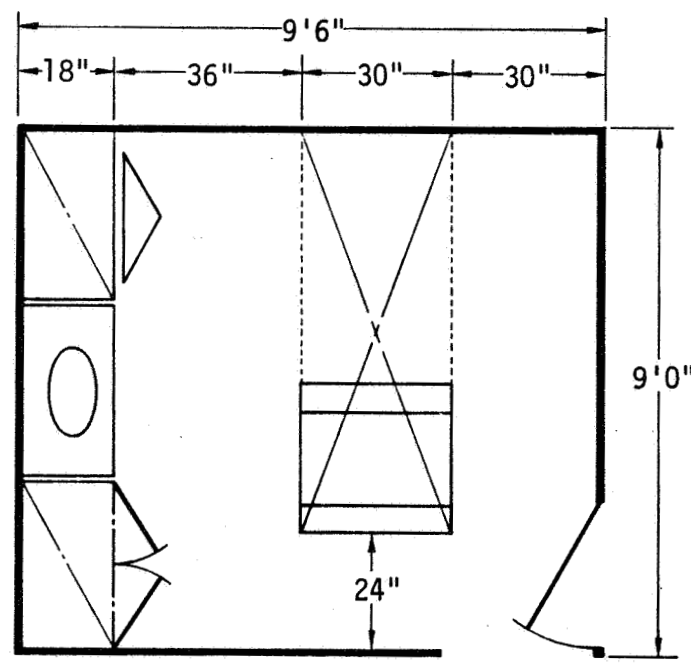
Color Effects: Cheering, relaxing



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Colors selected are based on those generally accepted in hospitals since this area might serve as a dispensary.

VOLUME

Remarks: The following recommendations are to be used for general guidance only; unless otherwise noted, the area recommendations pertain to an artificial gravity environment. To make maximum use of the area, it may also function as a dispensary since the physical layout and net space requirements are similar and the frequency of usage of both would probably be low. Gross Area = 85.5 ft^2. Ceiling height is 6'6".



2.4 WORK AREAS

2.4.1 Equipment.

Description: Mood: Physical Activity
Activity: Moderate
Social Factor: Public

LIGHTING

Light Source: Incandescent-Halogen cycle, fluorescent, mercury vapor

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	10-20	20-10

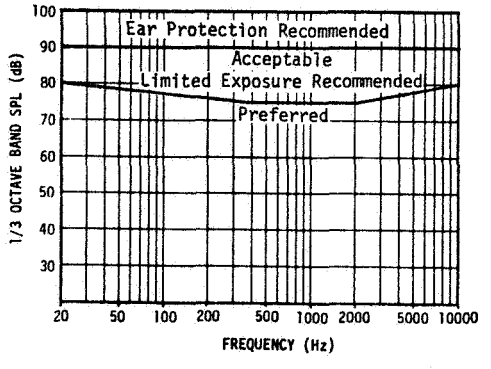
SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	60-90	90-60
Walls	40-60	60-40
Floors	20-40	40-15
Machines	25-45	45-20
Control Panel	20-40	40-20
Instruments	25-45	45-20

Remarks: General, low maintenance lighting equipment should be provided. For emergency purposes, lighting should have a secondary backup power source. Discharge type sources may create stroboscopic effects in rotating equipment which might be dangerous. Instrument panels should be self-lighted or designed to minimize reflections in the panels from the overhead lighting. Equipment colors should be coded to reflect their use or danger.

ACOUSTICS

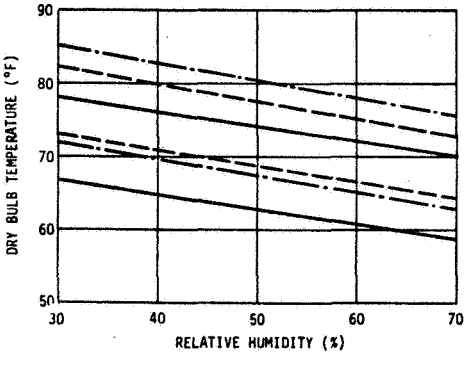
SOUND PRESSURE LEVEL



Remarks: None

TEMPERATURE

COMFORT ZONES

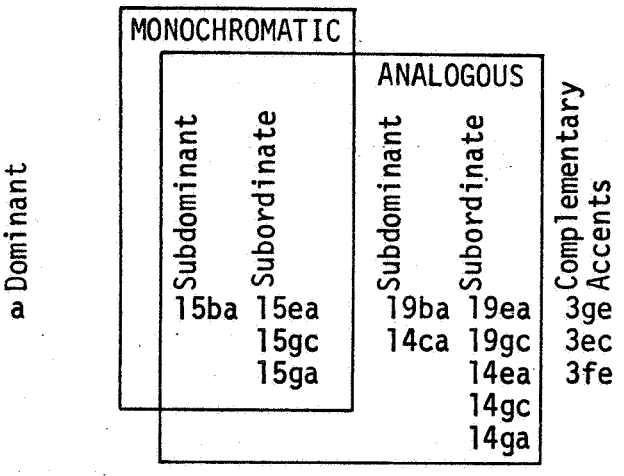


LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.8 to 1.0
Air Flow Rate: 80 fpm
Metabolic Rate: 800 to 1600 Btu/hr
Occupancy Time: 2 hrs/day

EXAMPLE COLOR SCHEME

Color Effects: Neutralizing



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Adequate lighting is provided for sight tasks. Basic cool hues are conducive to feelings of spaciousness, responsibility, and tend to make time pass more rapidly. Low color intensity and value contrasts serve to complement attentiveness.

VOLUME

Remarks: Area requirement of activity is mission equipment dependent.

2.4.2 Maintenance.

Description: Mood: Physical Activity
Activity: Moderate
Social Factor: Public

LIGHTING

Light Source: Incandescent-halogen cycle, fluorescent, mercury vapor

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	50-100	100-30

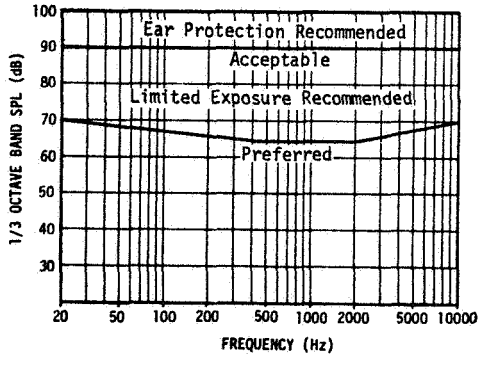
SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	40-90	90-40
Walls	40-60	60-40
Floors	20-40	40-15
Machines	25-45	45-20
Control Panel	20-40	40-20
Instruments	25-45	45-20

Remarks: Localized higher lighting levels are necessary over machining operations and areas of fine detail work. Care should be given to reflect glare present in attempting to read specular metal machine tools.

ACOUSTICS

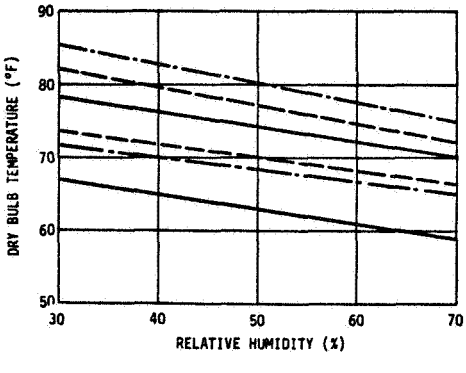
SOUND PRESSURE LEVEL



Remarks: None

TEMPERATURE

COMFORT ZONES

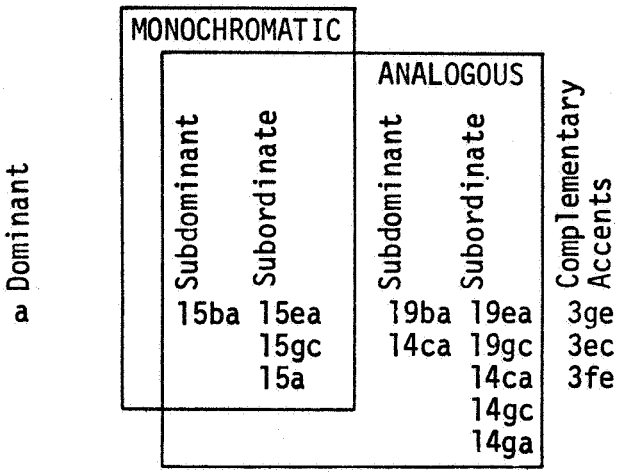


LEGEND: ——— 5 PSIA
– – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.8 to 1.0
Air Flow Rate: 80 fpm
Metabolic Rate: 800 to 1600 Btu/hr
Occupancy Time: 2.5 hrs/day

EXAMPLE COLOR SCHEME

Color Effects: Neutralizing



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Adequate lighting is provided for sight tasks. Basic cool hues are conducive to feelings of spaciousness, responsiblity, and tend to make time pass more rapidly. Low color intensity and value contrasts serve to complement attentiveness.

VOLUME

Remarks: Area requirement of activity is mission equipment dependent.

2.4.3 Power.

Description: Mood: Physical Activity
Activity: Moderate
Social Factor: Public

LIGHTING

Light Source: Incandescent-Halogen cycle, fluorescent, mercury vapor

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	10-20	20-10

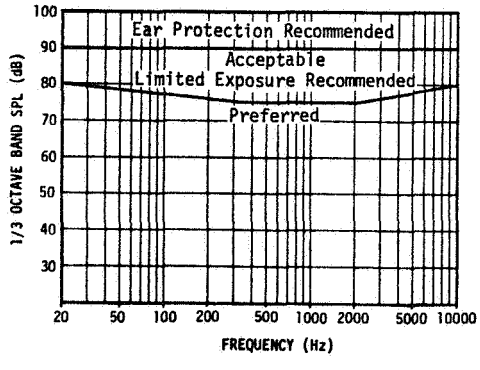
SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	60-90	90-60
Walls	40-60	60-40
Floors	15-35	40-15
Machines	25-45	45-20
Control Panel	20-40	40-20
Instruments	25-45	45-20

Remarks: General, low maintenance lighting equipment should be provided. For emergency purposes lighting should have a secondary backup power source. Discharge type sources may create stroboscopic effects in rotating equipment which might be dangerous. Instrument panels should be self-lighted or designed to minimize reflections in the panels from the overhead lighting. Equipment colors should be coded to reflect their use or danger.

ACOUSTICS

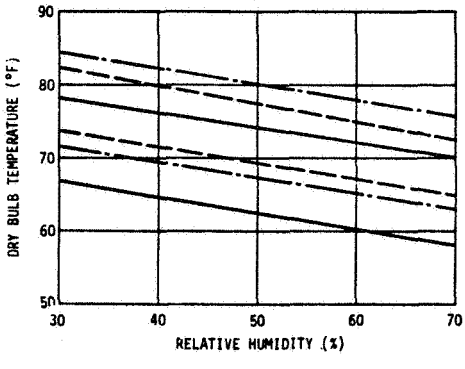
SOUND PRESSURE LEVEL



Remarks: None

TEMPERATURE

COMFORT ZONES

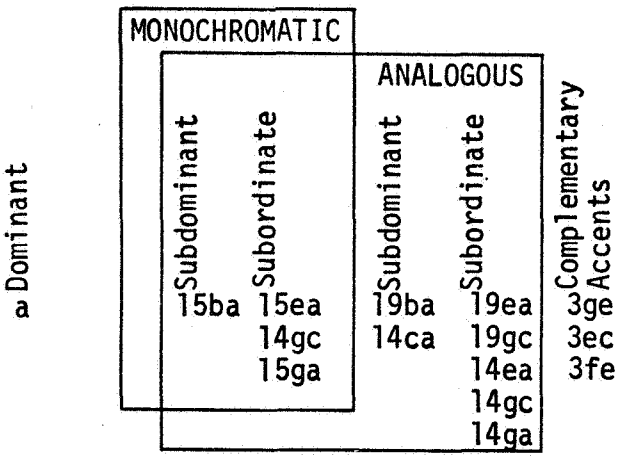


LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.8 to 1.0
Air Flow Rate: 80 fpm
Metabolic Rate: 800 to 1500 Btu/hr
Occupancy Time: 1 hr/day

EXAMPLE COLOR SCHEME

Color Effects: Neutralizing



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Adequate lighting is provided for sight tasks. Basic cool hues are conducive to feelings of spaciousness, responsibility, and tend to make time pass more rapidly. Low color intensity and value contrasts serve to complement attentiveness.

VOLUME

Remarks: Area requirement of activity is mission equipment dependent.

2.4.4 Food Storage.

Description: Mood: Physical Activity
Activity: Moderate
Social Factor: Public

LIGHTING

Light Source: Incandescent-Halogen cycle

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	5-10	10-5

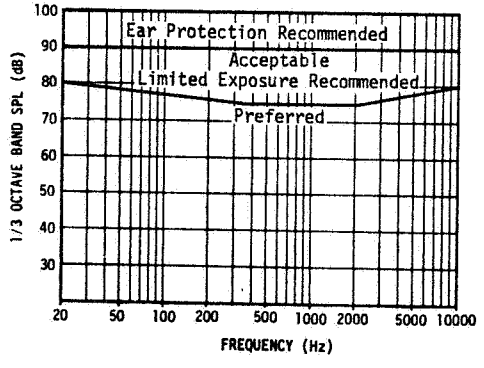
SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	60-90	90-60
Walls	35-60	60-35
Floors	15-35	35-15

Remarks: Lighting should be adequate for proper identification of products. Shelves should be shallow for ease of seeing products located on rear of shelf. Lighting should be utilitarian in nature.

ACOUSTICS

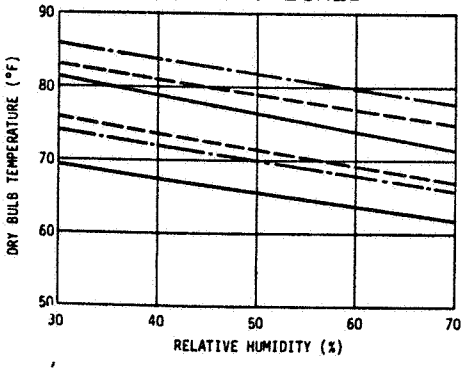
SOUND PRESSURE LEVEL



Remarks: None

TEMPERATURE

COMFORT ZONES

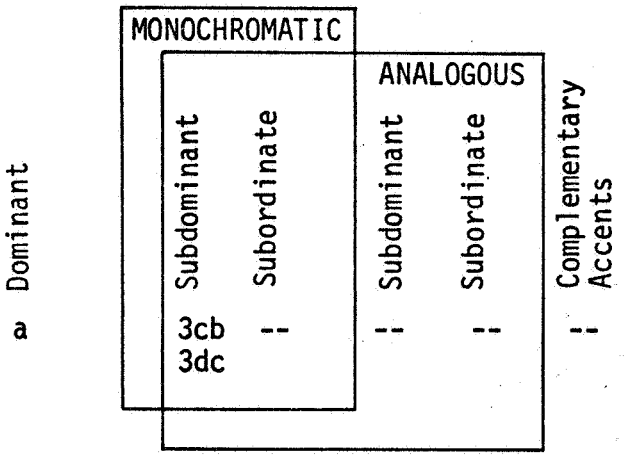


LEGEND: ——— 5 PSIA
- - - - - 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.8 to 1.0
Air Flow Rate: 80 fpm
Metabolic Rate: 750 Btu/hr
Occupancy Time: 0.5 hr/day

EXAMPLE COLOR SCHEME

Color Effects: Neutralizing



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Adequate light is provided.
Neutral colors are recommended for storage areas.

VOLUME

Remarks: Physical description of activity is mission dependent.

2.4.5 Supply.

Description: Mood: Physical Activity
Activity: Moderate
Social Factor: Public

LIGHTING

Light Source: Incandescent-Halogen cycle, fluorescent, mercury vapor

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	15-20	20-5

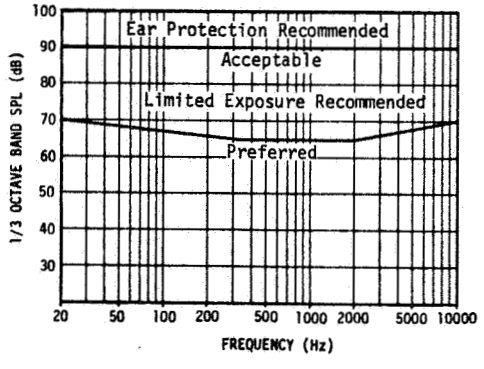
SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	60-90	90-60
Walls	40-60	70-40
Floors	20-40	40-15

Remarks: Lighting should be adequate to provide illumination of storage and dispensing areas to insure proper product identification. If color identification is important, color of sources should have high color rendering index.

ACOUSTICS

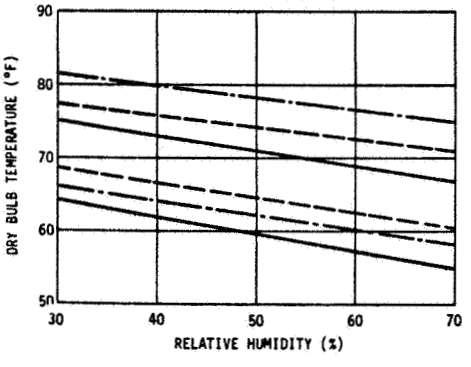
SOUND PRESSURE LEVEL



Remarks: None

TEMPERATURE

COMFORT ZONES

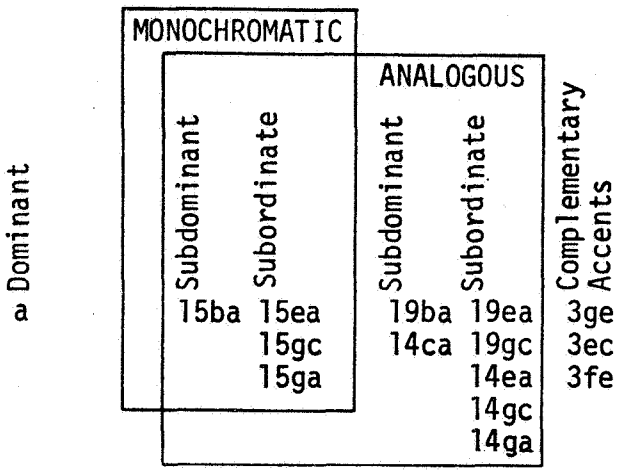


LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.8 to 1.0
Air Flow Rate: 70 fpm
Metabolic Rate: 1000 Btu/hr
Occupancy Time: 1 hr/day

EXAMPLE COLOR SCHEME

Color Effects: Neutralizing



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Adequate lighting is provided for sight tasks. Basic cool hues are conducive to feelings of spaciousness, responsibility, and tend to make time pass more rapidly. Low color intensity and value contrasts serve to complement attentiveness.

VOLUME

Remarks: Area requirement of activity is mission equipment dependent.

2.4.6 Control Room.

Description: Mood: Mental concentration
Activity: Moderate to low
Social Factor: Public

LIGHTING

Light Source: Fluorescent-deluxe colors, metal halide

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	50-70	70-20

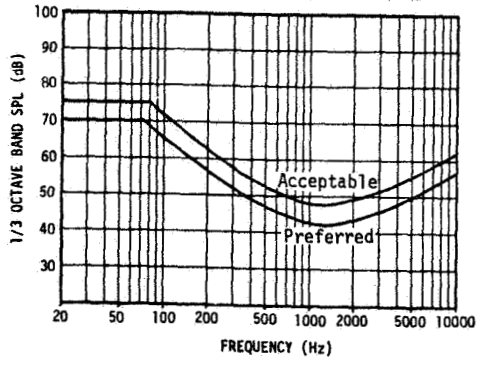
SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	60-90	90-60
Walls	40-60	60-40
Floors	15-35	35-15
Machines	25-45	45-20
Control Panel	20-40	40-20
Instruments	25-45	45-20

Remarks: Lighting should be efficient and functional with emphasis over specific working areas. Higher levels should be provided over areas where specific detailed work is being performed, e.g., navigational, chart reading. Colors should be cool but stimulating.

ACOUSTICS

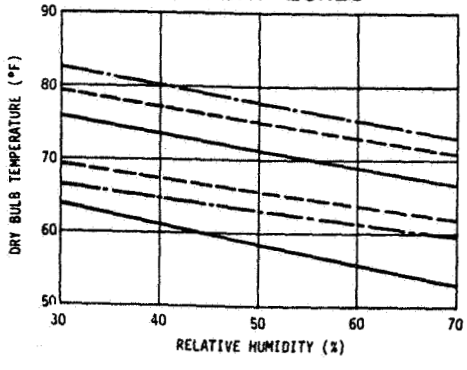
SOUND PRESSURE LEVEL



Remarks: Annoying noise sources (intermittent, high-pitched, unlocalized) must be avoided to preclude interference with mental tasks. SIL levels below 60 dB must be maintained to promote close face-to-face communication. From standpoint of noise control, ideal wall, ceiling, and floor should be massive with rough porous surface.

TEMPERATURE

COMFORT ZONES

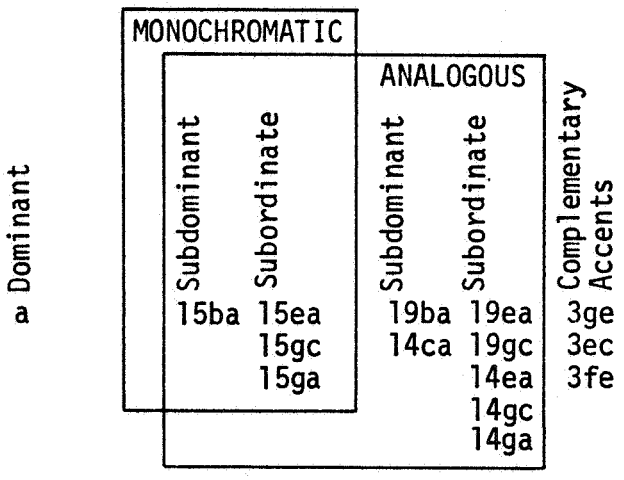


LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.8 to 1.0
Air Flow Rate: 60 fpm
Metabolic Rate: 750 Btu/hr
Occupancy Time: 8 hrs/day

EXAMPLE COLOR SCHEME

Color Effects: Neutralizing



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Adequate lighting is provided for sight tasks. Basic cool hues are conducive to feelings of spaciousness, responsibility, and tend to make time pass more rapidly. Low color intensity and value contrasts serve to complement attentiveness.

VOLUME

Remarks: Area requirement of activity is mission equipment dependent.

2.4.7 Communications.

Description: Mood: Mental concentration
Activity: Moderate to low
Social Factor: Public

LIGHTING

Light Source: Fluorescent-deluxe colors, metal halide

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	50-70	70-20

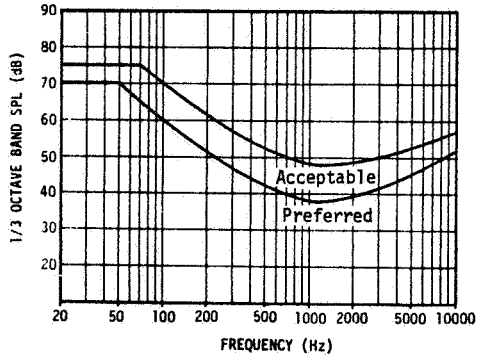
SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	60-90	90-60
Walls	40-60	60-40
Floors	15-35	35-15
Machines	25-45	45-20
Control Panel	20-40	40-20
Instruments	25-45	45-20

Remarks: Lighting should be efficient and functional with emphasis over specific working areas. Higher levels should be provided over areas where specific detailed work is being performed; e.g., navigational, chart reading. Colors should be cool but stimulating.

ACOUSTICS

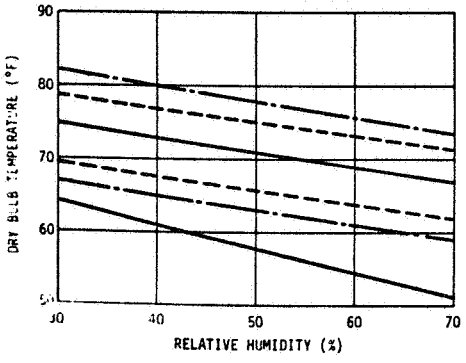
SOUND PRESSURE LEVEL



Remarks: Annoying noise sources (intermittent, high-pitched, unlocalized) must be avoided to preclude interference with mental tasks. SIL levels below 60 dB must be maintained to promote close face-to-face communication. From the standpoint of noise control, ideal wall, ceiling and floor should be massive with rough porous surface.

TEMPERATURE

COMFORT ZONES

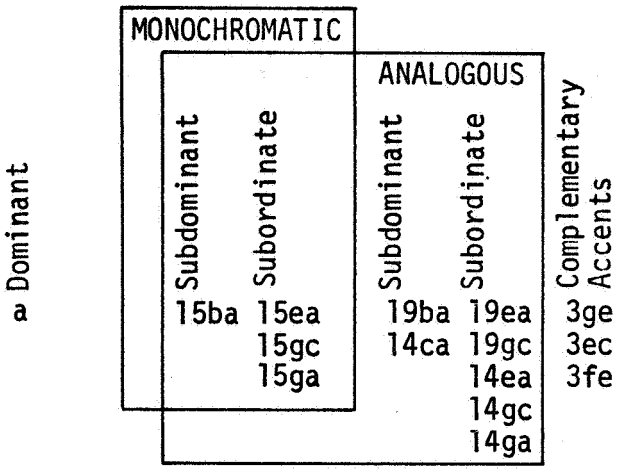


LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.8 to 1.0
Air Flow Rate: 60 fpm
Metabolic Rate: 800 Btu/hr
Occupancy Time: 8 hrs/day

EXAMPLE COLOR SCHEME

Color Effect: Neutralizing



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Adequate lighting is provided for sight tasks. Basic cool hues are conducive to feelings of spaciousness, responsibility, and tend to make time pass more rapidly. Low color intensity and value contrasts serve to complement attentiveness.

VOLUME

Remarks: Area requirement of activity is mission equipment dependent.

2.4.8 Computer.

Description: Mood: Mental concentration
Activity: Moderate to low
Social Factor: Public

LIGHTING

Light Source: Fluorescent, metal halide

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	50-70	70-20

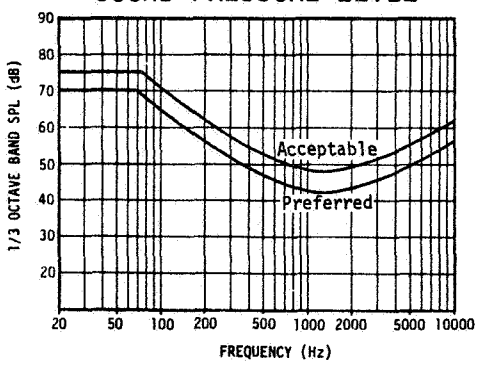
SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	60-90	90-60
Walls	40-60	60-40
Floors	15-35	35-15
Machines	25-45	45-20
Control Panel	20-40	40-20

Remarks: Lighting should be efficient and functional with emphasis over specific working areas. Higher levels should be provided over areas where specific detailed work is being performed; e.g., navigational, chart reading. Colors should be cool but stimulating.

ACOUSTICS

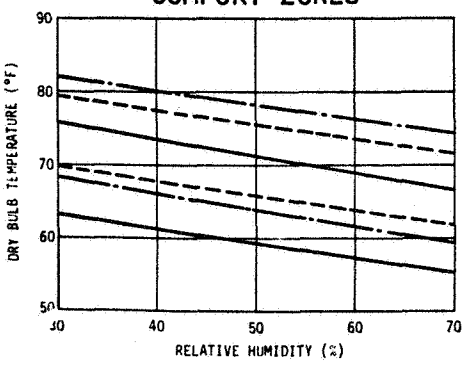
SOUND PRESSURE LEVEL



Remarks: None

TEMPERATURE

COMFORT ZONES

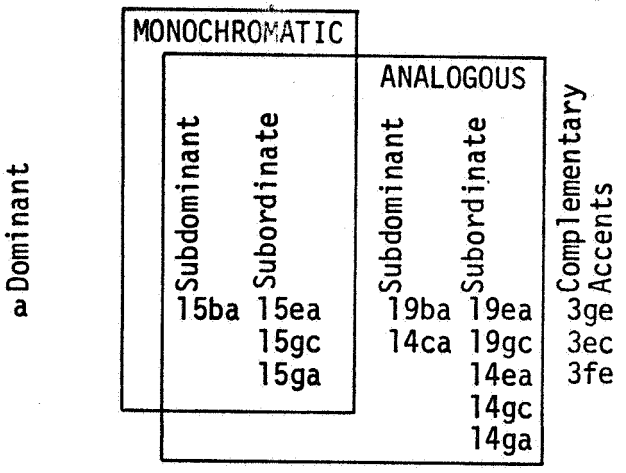


LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.8 to 1.0
Air Flow Rate: 60 fpm
Metabolic Rate: 700 Btu/hr
Occupancy Time: 8 hrs/day

EXAMPLE COLOR SCHEME

Color Effect: Neutralizing



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Adequate lighting is provided for sight tasks. Basic cool hues are conducive to feelings of spaciousness, responsibility, and tend to make time pass more rapidly. Low color intensity and value contrasts serve to complement attentiveness.

VOLUME

Remarks: Area requirement of activity is mission equipment dependent.

2.4.9 Shop.

Description: Mood: Physical Activity
Activity: Moderate to high
Social Factor: Public

LIGHTING

Light Source: Incandescent-Halogen cycle, fluorescent, mercury vapor

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	50-70	70-20

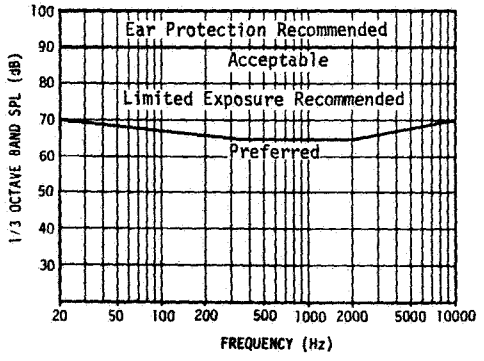
SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	65-90	90-60
Walls	40-60	60-40
Floors	20-50	50-20
Machines	25-45	45-20
Control Panel	20-40	40-20

Remarks: Lighting should be efficient and functional with emphasis over specific working areas. Higher levels should be provided over areas where specific detailed work is being performed; e.g., navigational, chart reading. Colors should be cool but stimulating.

ACOUSTICS

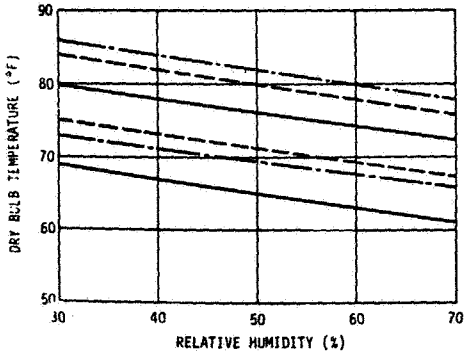
SOUND PRESSURE LEVEL



Remarks: None

TEMPERATURE

COMFORT ZONES

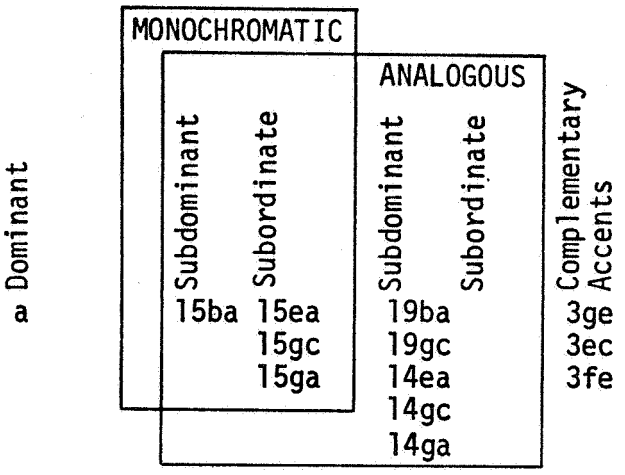


LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.8 to 1.0
Air Flow Rate: 80 fpm
Metabolic Rate: 1250 Btu/hr
Occupancy Time: 6 hrs/day

EXAMPLE COLOR SCHEME

Color Effects: Neutralizing



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Adequate lighting is provided for sight tasks. Basic cool hues are conducive to feelings of spaciousness, responsibility, and tend to make time pass more rapidly. Low color intensity and value contrasts serve to complement attentiveness.

VOLUME

Remarks: Area requirement of activity is mission equipment dependent.

2.4.10 Offices.

Description: Mood: Mental concentration
Activity: Moderate
Social Factor: Public

LIGHTING

Light Source: Fluorescent, metal halide

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	50-70	70-20

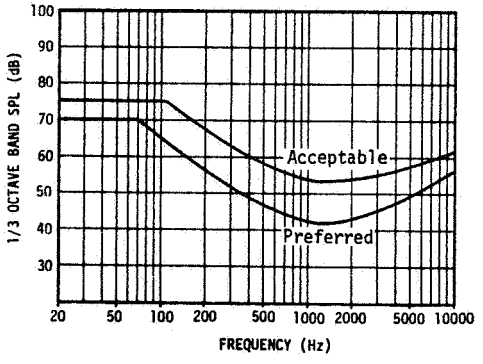
SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	60-90	90-60
Walls	40-60	60-40
Floors	15-35	35-15
Furniture	20-45	45-20
Machines	25-45	45-20

Remarks: Lighting should be efficient and functional with emphasis over specific working areas. Higher levels should be provided over areas where specific detailed work is being performed, e.g., navigational, chart reading. Colors should be cool but stimulating.

ACOUSTICS

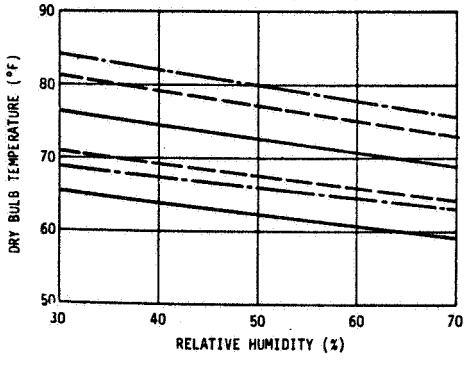
SOUND PRESSURE LEVEL



Remarks: Annoying noise sources (intermittent, high-pitched, unlocalized) must be avoided to preclude interference with mental tasks. SIL levels below 60 dB must be maintained to promote close face-to-face communication. From standpoint of noise control, ideal wall, ceiling, and floor should be massive with rough porous surface.

TEMPERATURE

COMFORT ZONES

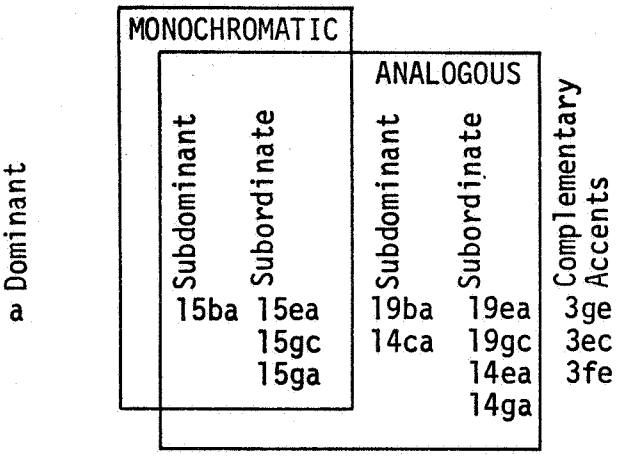


LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.8 to 1.0
Air Flow Rate: 60 fpm
Metabolic Rate: 700 Btu/hr
Occupancy Time: 8 hrs/day

EXAMPLE COLOR SCHEME

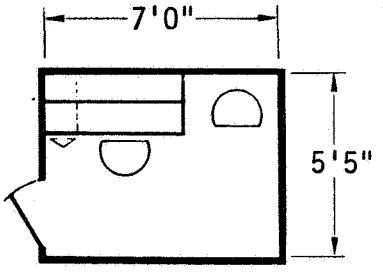
Color Effects: Neutralizing



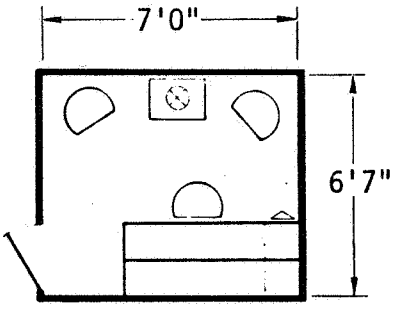
Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Adequate light is provided for sight tasks. Basic cool hues are conducive to feelings of spaciousness and responsibility. Low color intensity and value contrasts serve to complement attentiveness.

VOLUME

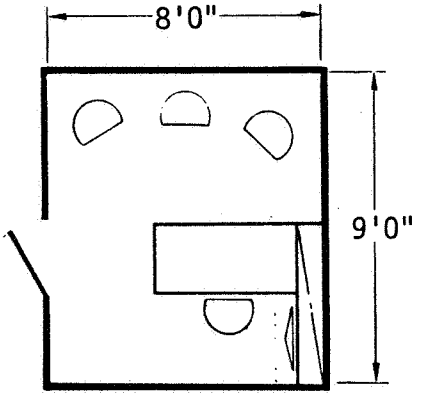
Remarks: The following recommendations are to be used for general guidance only; unless otherwise noted, the area recommendations pertain to an artificial gravity environment. Office area requirement must be determined on an individual basis once the associated equipment and the tasks of the occupant(s) are defined. The three example layouts shown represent guideline sizes for a station commander for missions with the following crew sizes: A=6-30, B=31-60, C=61-100. Ceiling Height = 6'6".



Office A
38 ft^2



Office B
46 ft^2



Office C
72 ft^2

2.4.11 Laboratories.

Description: Mood: Mental concentration
Activity: Moderate
Social Factor: Public

LIGHTING

Light Source: Incandescent-halogen cycle, fluorescent, mercury vapor

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	50-70	70-20

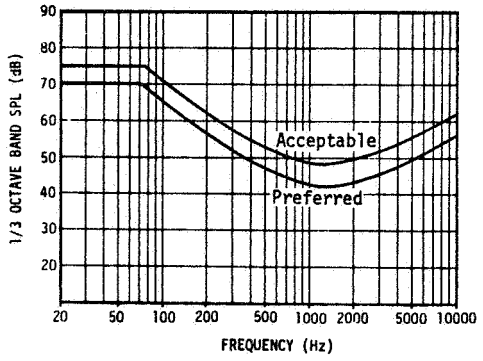
SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	70-90	90-65
Walls	50-70	70-50
Floors	20-40	40-20
Furniture	45-80	85-35
Machines	25-45	45-20

Remarks: Lighting similar to office areas, being efficient and functional with emphasis over work benches. If color is essential in making identifications, sources with high color rendering index are necessary. Adequate lighting of exhaust hoods and climate chambers should be provided for proper observation of experiments.

ACOUSTICS

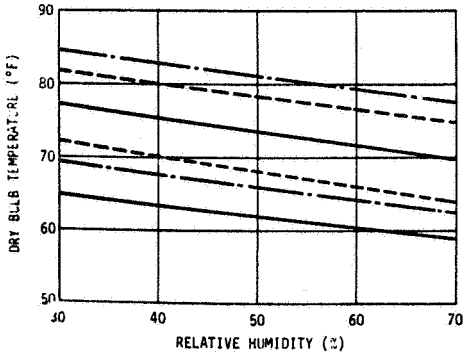
SOUND PRESSURE LEVEL



Remarks: Annoying noise sources, (intermittent, high-pitched, unlocalized) must be avoided to preclude interference with mental tasks. SIL levels below 60 dB must be maintained to promote close face-to-face communication. From standpoint of noise control, ideal wall, ceiling, and floor should be massive with rough porous surface.

TEMPERATURE

COMFORT ZONES

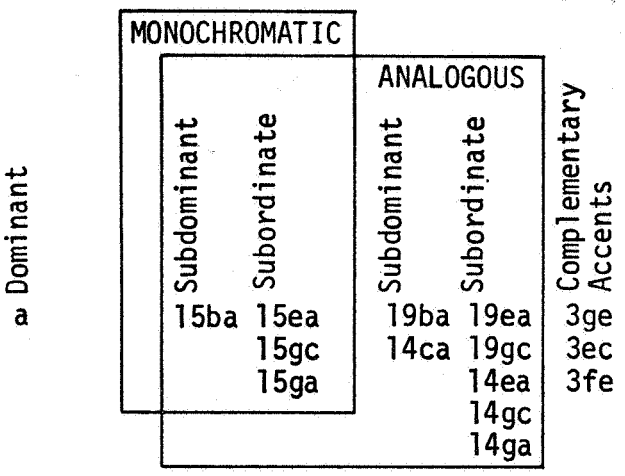


LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.8 to 1.0
Air Flow Rate: 70 fpm
Metabolic Rate: 1000 Btu/hr
Occupancy Time: 6 hrs/day

EXAMPLE COLOR SCHEME

Color Effect: Neutralizing



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Adequate lighting is provided for sight tasks. Basic cool hues are conducive to feelings of spaciousness, responsibility, and tend to make time pass more rapidly. Low color intensity and value contrasts serve to complement attentiveness.

VOLUME

Remarks: Area requirement of activity is mission equipment dependent.

2.4.12 Dock.

Description: Mood: Physical Activity
Activity: Moderate to high
Social Factor: Public

LIGHTING

Light Source: Incandescent-halogen cycle, fluorescent, mercury vapor

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	10-30	30-10

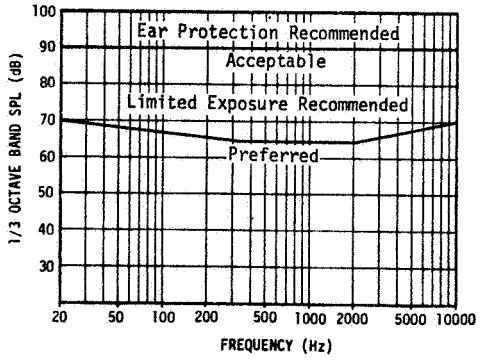
SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	60-90	90-60
Walls	40-60	60-40
Floors	15-35	35-15

Remarks: Lighting should be adequate for general safety, identification of products, movement of materials, and storage. Color coding would be useful in identifying and handling.

ACOUSTICS

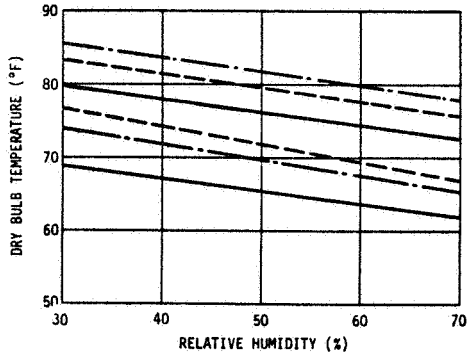
SOUND PRESSURE LEVEL



Remarks: None

TEMPERATURE

COMFORT ZONES

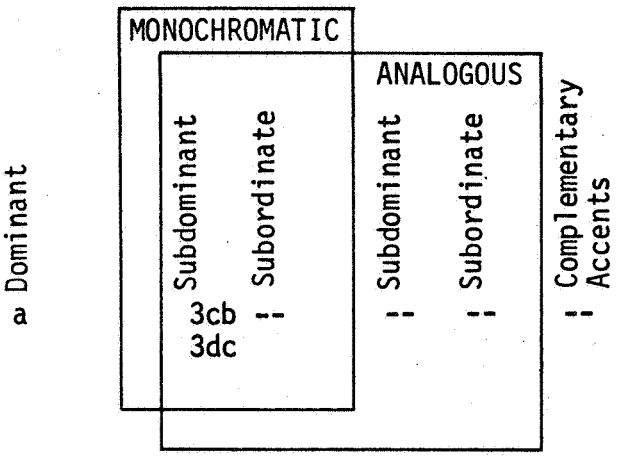


LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.8 to 1.0
Air Flow Rate: 80 fpm
Metabolic Rate: 800 to 1500 Btu/hr
Occupancy Time: 3 hrs/day

EXAMPLE COLOR SCHEME

Color Effect: Neutralizing



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Adequate light is provided.
Neutral colors are used in this area because it is an area of transition.

VOLUME

Remarks: Physical description of activity is mission dependent.

2.4.13 Photographic Support.

Description: Mood: Mental concentration
Activity: Low
Social Factor: Public

LIGHTING

Light Source: Incandescent-halogen cycle

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	0-30	30-0

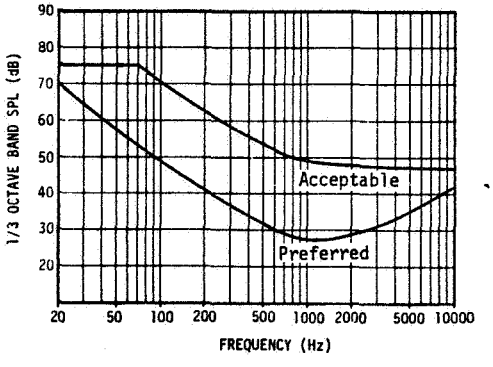
SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	60-90	90-60
Walls	40-60	60-40
Floors	15-35	35-15
Machines	25-45	45-20

Remarks: Lighting must be capable of being reduced below the sensitivity requirements of the films and other photographic products being used. Adequate safety lights should be provided for the dark adapted environment.

ACOUSTICS

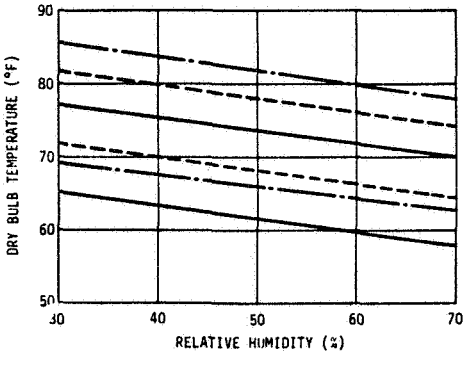
SOUND PRESSURE LEVEL



Remarks: Annoying noise sources (intermittent, high-pitched, unlocalized) must be avoided to preclude interference with mental tasks. SIL levels below 60 dB must be maintained to promote close face-to-face communication. From standpoint of noise control, ideal wall, ceiling, and floor should be massive with rough porous surface.

TEMPERATURE

COMFORT ZONES

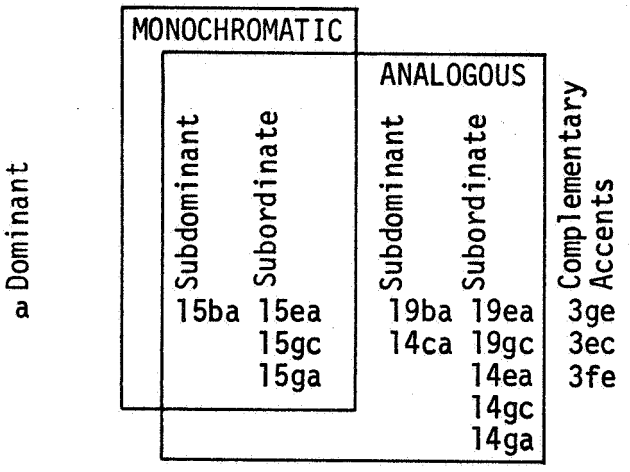


LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.8 to 1.0
Air Flow Rate: 70 fpm
Metabolic Rate: 700 Btu/hr
Occupancy Time: 4 hrs/day

EXAMPLE COLOR SCHEME

Color Effect: Neutralizing



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Adequate lighting is provided for sight tasks. Basic cool hues are conducive to feelings of spaciousness, responsibility, and tend to make time pass more rapidly. Low color intensity and value contrasts serve to complement attentiveness.

VOLUME

Remarks: Area requirement of activity is mission equipment dependent.

2.4.14 Animal Housing.

Description: Mood: Physical Activity
Activity: Moderate
Social Factor: Public

LIGHTING

Light Source: Incandescent-halogen cycle, fluorescent, mercury vapor

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	5-50	50-1

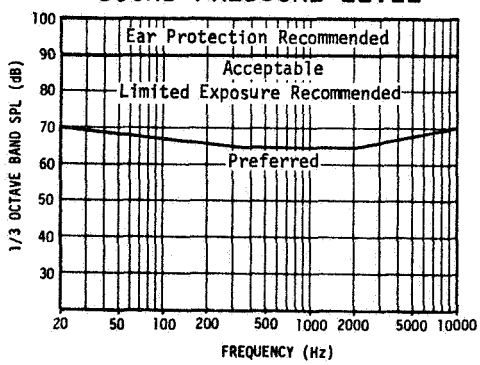
SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	60-90	90-60
Walls	35-60	60-35
Floors	15-35	35-15
Machines	25-45	45-20

Remarks: Lighting should be sufficient for general hygiene purposes. Close inspection of animals could be achieved with localized lighting. Control of the lighting levels and spectral composition may be desirable for investigation and/or control of animal and plant growing cycles.

ACOUSTICS

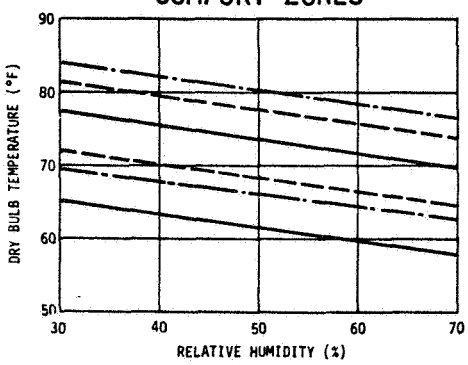
SOUND PRESSURE LEVEL



Remarks: None

TEMPERATURE

COMFORT ZONES

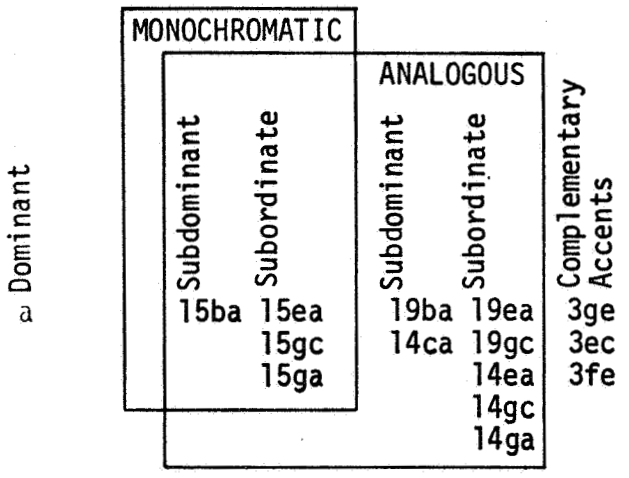


LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.8 to 1.0
Air Flor Rate: 70 fpm
Metabolic Rate: 800 Btu/hr
Occupancy Time: 3 hrs/day

EXAMPLE COLOR SCHEME

Color Effect: Neutralizing



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Adequate lighting is provided for sight tasks. Basic cool hues are conducive to feelings of spaciousness, responsibility, and tend to make time pass more rapidly. Low color intensity and value contrasts serve to complement attentiveness.

VOLUME

Remarks: Area requirement of activity is mission equipment dependent.

2.4.15 Agricultural Study.

Description: Mood: Physical Activity
Activity: Moderate
Social Factor: Public

LIGHTING

Light Source: Incandescent-halogen cycle, fluorescent, mercury vapor

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	5-50	50-1

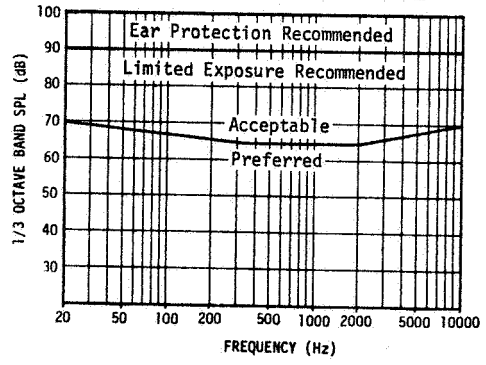
SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	60-90	90-60
Walls	35-60	60-35
Floors	15-35	35-15
Machines	25-45	45-20

Remarks: Lighting should be sufficient for general hygiene purposes. Close inspection of animals could be achieved with localized lighting. Control of the lighting levels and spectral composition may be desirable for investigation and/or control of animal and plant growing cycles.

ACOUSTICS

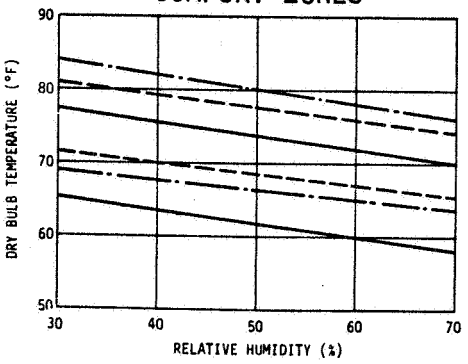
SOUND PRESSURE LEVEL



Remarks: None

TEMPERATURE

COMFORT ZONES

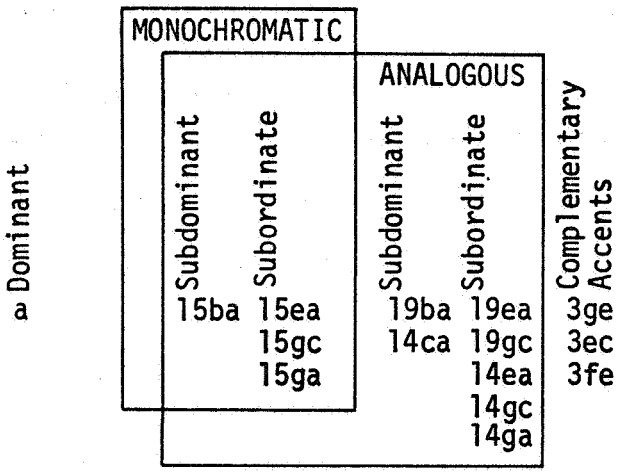


LEGEND: ——— 5 PSIA
– – – – – 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.8 to 1.0
Air Flow Rate: 70 fpm
Metabolic Rate: 800 Btu/hr
Occupancy Time: 6 hrs/day

EXAMPLE COLOR SCHEME

Color Effects: Neutralizing



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Adequate lighting is provided for sight tasks. Basic cool hues are conducive to feelings of spaciousness, responsibility, and tend to make time pass more rapidly. Low color intensity and value contrasts serve to complement attentiveness.

VOLUME

Remarks: Area requirement of activity is mission equipment dependent.

2.4.16 Air Lock.

Description: Mood: Physical Activity
Activity: Moderate to high
Social Factor: Public

LIGHTING

Light Source: Incandescent, fluorescent, mercury vapor

LIGHT LEVEL

	Desirable	Max-Min
Foot Candles	5-10	10-1

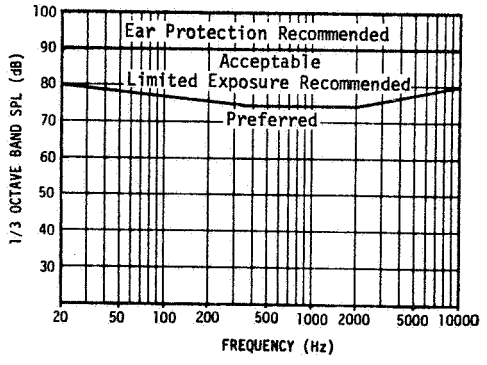
Remarks: Same considerations as for hallways. Lighting should be designed for transition aspects of area.

SURFACE REFLECTANCE (%)

	Desirable	Max-Min
Ceiling	70-90	90-70
Walls	50-70	70-50
Floors	20-40	40-20
Control Panel	20-40	40-20
Instruments	25-45	45-20

ACOUSTICS

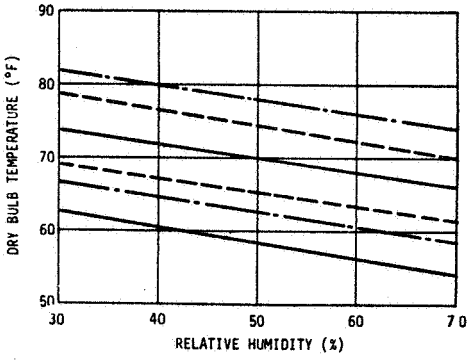
SOUND PRESSURE LEVEL



Remarks: None

TEMPERATURE

COMFORT ZONES

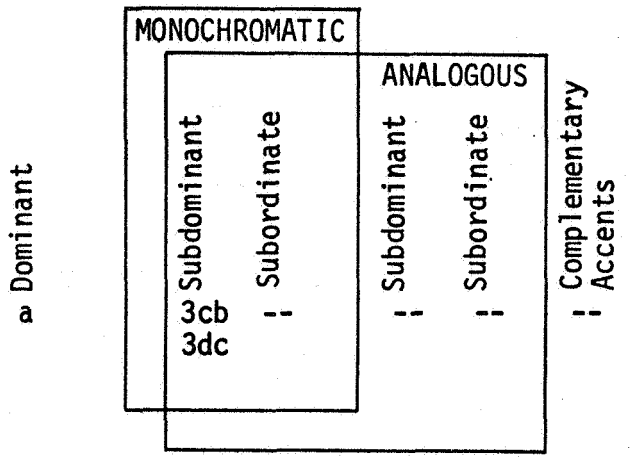


LEGEND: ——— 5 PSIA
- - - - - 10 PSIA
—·— 14.7 PSIA

Clo Factor: 0.8 to 1.0
Air Flow Rate: 60 fpm
Metabolic Rate: 850 Btu/hr
Occupancy Time: 1 hr/day

EXAMPLE COLOR SCHEME

Color Effects: Neutralizing



Remarks: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however, it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Adequate light is provided.
Neutral colors are used in this area because it is an area of transition.

VOLUME

Remarks: Physical description of activity is mission dependent.

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3.0 SPECIFIC ENVIRONMENTAL ELEMENTS

This section provides the designer with a general understanding of the effect and importance of the environmental elements of habitability listed below. Each of these elements is discussed in relation to applicable effects of the environment on man, and how man is to control these elements in order to optimize his environment.

Specific Environmental Elements

- Lighting
- Color
- Acoustics
- Volume
- Temperature

3.1 LIGHTING

3.1.1 Requirements. Both the proper quantity and proper quality of light within an enclosed habitat and in the total seeing environment create an atmosphere which has a positive effect on the health, safety and comfort of the personnel. Thus, proper lighting improves personnel morale, motivation, and output efficiency. Poor visual environments caused by low levels of illumination, glaring fixtures, and highly reflective surfaces will affect personnel visual performance. This directly affects the speed and accuracy in the performance of required tasks. In addition, it will also cause reduced alertness due to eyestrain and fatigue, thus increasing the chance of an accident. It is therefore apparent that lighting design encompasses considerably more than the specification of illumination levels. It collectively involves consideration of the total luminous environment in which inhabitants of the closed environment must live and perform their various tasks.

3.1.2 Definitions.

Light - That part of the radiant energy spectrum which can be seen by the human eye. The electromagnetic spectrum includes radiant energy of many wavelengths, but only a narrow band, from about 400 to 700 millimicrons, is visible to the normal eye for vision.

Candela - Unit of luminous intensity of a light source in a specified direction. Defined as 1/60 the intensity of a square centimeter of a black body radiator operated at the freezing point of platinum (2047°K).

Lumen - A unit to measure the intensity of luminous output of lamps and luminaires. Defined as the rate at which light falls on a one square foot area surface which is equally distant one foot from a source whose intensity is one candela.

Illumination - Amount of light incident upon a surface measured in foot candles.

Footcandle - The measure of illumination at any point that is a distance of one foot from a uniform point source of one candle power. It is also equivalent to a density of one lumen uniformly distributed over an area of one square foot.

Brightness - That which the eye actually sees and is the result of light being reflected or emitted by a surface directly into the eye. Measured in foot lamberts or candelas per square inch.

Foot Lambert - The measure of brightness of a surface, when viewed from a particular direction, emitting, or reflecting one lumen per square foot.

Contrast - A measure of the brightness of an object compared to its immediate surroundings.

Reflectance - The ratio of the flux reflected by a surface or medium to the incident flux. In simplified terms it is the ratio of the brightness to the illumination.

Glare - The sensation produced by brightness within the visual field that is sufficiently greater than the luminance to which the eyes are adapted to cause annoyance, discomfort or loss in visual performance and visibility.

Visual Acuity - The ability to distinguish fine details. Quantitatively, the reciprocal of the angular size in minutes of the critical detail which is just large enough to be seen.

Lamp Source - A generic term for an artificial source of light.

Luminaire - A complete lighting unit consisting of a lamp, or lamps together with the parts designed to distribute the light, to position and protect the lamps, and to connect the lamps to the power supply.

Color Temperature - As applied to a light source, refers to the absolute temperature in degrees Kelvin of a theoretical black body or full radiator whose color appearance matches that of the source in question.

3.1.3 Engineering Data.

3.1.3.1 Quantity of Lighting. The quantity of light should be tailored to the seeing tasks involved. This is accomplished by specifying the illumination on a surface as measured in foot candles. Table 3-1 presents some general illumination levels for various seeing tasks. See Section 2.0 of this document for particular crew area illumination criteria.

3.1.3.2 Quality of Lighting. The quality of light refers to the proper distribution and control of light within the habitat. This requires the proper balance of brightness in the whole visual environment.

3.1.3.2.1 Brightness Ratios - Excessive brightness ratios in the field of view, or brightness contrasts between adjacent surfaces, even though not severe enough to be called glare, may be seriously detrimental to lighting quality. A high brightness of the work surface with a comparatively low brightness of the surroundings is undesirable, since it forces continual adjustments of the eyes from one brightness level to the other. Brightness in the peripheral field higher than the brightness of the work surface tends to attract the eye away from the task. For these reasons it is desirable to maintain a comfortable balance of perceived luminances in the luminous environment to prevent eye fatigue.

The brightness or luminance of a surface can be approximated by taking a reading with a standard light meter held approximately 2 to 4 inches from the surface. If the meter reading from the task is 100 and a reading from the surrounding surface is 50, the brightness ratio is 100:50 or 2 to 1. Recommended maximum brightness ratios are provided in Table 3-2.

3.1.3.2.2 Glare - Substantial losses in task contrast, hence, in visibility and visual performance, can result when light sources are reflected in specular or semi-specular visual tasks. This effect can be insidious in the fact that it can occur even in seemingly matte-type tasks. Table 3-3 lists types of surface reflectances. Table 3-4 lists types of glare and provides suggestive reduction methods.

3.1.3.2.3 Reflectance - The reflectance of the ceilings, walls, floors and furnishings contributes significantly to the general illumination level. As the reflectance of a surface is increased, its brightness is also increased. This makes it essential to pay particular attention to the brightness ratio of all visible surfaces so visual comfort is maintained. See Section 4.0 of this document for particular crew area reflectance requirements (Refer to Tables 4-17, 4-18, and 4-19).

3.1.3.3 Illumination Methods. The five general illumination methods are shown in Table 3-5.

(Text continued on page 3-7)

Table 3-1. General Illumination Levels for Various Tasks

Task (Seeing)	Description	Illumination (ft c)		
		Maximum	Desirable Range	Minimum
General	General lighting requirements for proper identification of items and general maintenance	10	5-10	1
Casual	Suitable for relaxing or reading, detailed maintenance, and movement of people	30	20-30	10
Functional	Emphasis placed on efficiency and functional aspects used for investigation and observation of experiments and animals	70	50-70	20
Medium Detail	Detail inspection and reading small markings	100	50-100	30
Fine Detail	Fine detail on intricate tasks examining human patients - generally short duration	1000	500-1000	100

Table 3-2. Maximum Brightness Ratios

Condition Between Task and Surfaces/Surroundings	Maximum Brightness Ratio for Optimum Seeing Conditions
Adjacent darker surroundings	3 to 1
Adjacent lighter surroundings	1 to 3
Remote darker surfaces	10 to 1
Remote lighter surfaces	1 to 10
Luminaires and surfaces adjacent	20 to 1
Within normal field of view	40 to 1

Table 3-3. Types of Surface Reflectances

Type	Description	Surface
Diffuse (matte surfaces)		Rough, irregular particles
Specular		Incident light on polished surface such as mirror, that is reflected at an angle equal to angle of incidence
Compound		Surfaces which are a combination of diffuse and specular

Table 3-4. Glare Reduction Methods

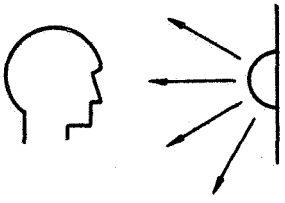
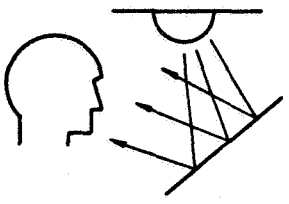
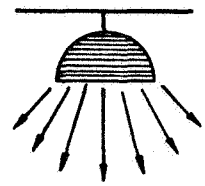
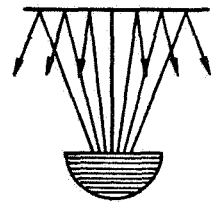
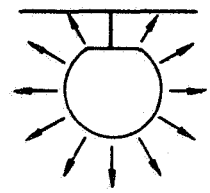
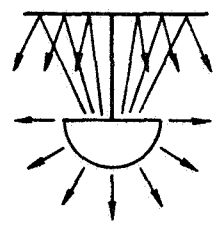
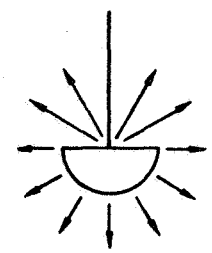
Type	Description	Reduction Methods
Direct		Avoid bright light sources within 60 degrees of the center of the visual field Use indirect lighting Use several low-intensity sources rather than one high intensity source Lights are placed high and directly above task area Use shields, hoods, and visors so that viewing area is shielded from direct light source
Indirect		Use diffuse light Use dull, unpolished surfaces Place direct light source so that viewing area is not equal to the angle of incidence

Table 3-5. Illumination Methods

Method	Description	Reflectance	Comments
Direct		0-10% ↕ 90-100%	90-100% of the output travels directly from the source to task area; gives maximum light, but has undesirable characteristics of brightness, contrast, shadows, and glare.
Indirect		90-100% ↕ 0-10%	90-100% of output is directed toward ceiling or away from task area, but method is less efficient since more power is required for same illumination level. Method eliminates shadows and glare and distributes light evenly.
Diffused		40-60% ↕ 40-60%	Source is enclosed in translucent bowl so that light is scattered evenly, more efficient than indirect but does cause glare and shadows.
Semi-Direct		10-40% ↕ 60-90%	60-90% is directed toward task area; combines advantages of direct and diffused illumination methods.
Semi-Indirect		60-90% ↕ 10-40%	10-40% is directed toward task area; combines advantages of indirect and diffused illumination methods.

3.1.3.4 Lamp Sources. The various lamp sources are shown in Table 3-6. Table 3-7 provides lamp source performance characteristics and Table 3-8 provides an evaluation of the various lamp sources. The results of the lamp source evaluation are provided in the summary, Table 3-9.

3.1.3.5 Luminaire Types. The types of luminaires are described in Table 3-10 and evaluated in Table 3-11.

3.1.3.6 Light Loss Causes. Table 3-12 lists various causes of illumination reduction levels.

3.1.3.7 Color Temperature in Lighting. All objects will emit light if they are heated to a sufficiently high temperature. As the object is raised in temperature, the color of the light emitted from it will change. Color designations for various black body temperatures are as follows:

Black Body Temperatures (°K)	Color Designation
300	Black
800	Red
3,000	Yellow
5,000	White
8,000	Pale Blue
60,000	Brilliant Blue

Technically, a color temperature designation can only be applied to incandescent sources and, as such, it is the specification of both the degree of whiteness and the spectral energy composition of the source. However, the term "apparent color temperature" is often used to specify the degree of whiteness of fluorescent lamps as well as mercury vapor lamps, etc.

Some lamps tend to flatter object colors which is another way of saying they emphasize the dominant color of the object while deemphasizing complementary colors. The color atmosphere effects of a few fluorescent sources as an example are as follows:

Fluorescent Lamp	Designation	Atmosphere Effects
Warm White	WW	Warm
Deluxe Warm White	WWX	Warm
Cool White	CW	Neutral to Moderately Cool
Deluxe Cool White	CWX	Neutral to Moderately Cool
White	W	Moderately Warm
Daylight	D	Very Cool

Table 3-6. Lamp Source Descriptions

Incandescent - general service: A lamp in which light is produced by a filament heated to incandescence by an electric current

Incandescent - tungsten-halogen: A regenerative lamp in which light is produced by heating of a metal filament. The lamp contains a halogen (Iodine) atmosphere enclosed in quartz which provides redeposition of tungsten back to the filament to achieve extended filament life.

Fluorescent: A low-pressure mercury electric-discharge lamp in which a fluorescing coating (phosphor) transforms some of the ultraviolet energy generated by the discharge into light. Colors are produced by use of special phosphors which convert the ultraviolet energy within the lamp to visible light of the desired wavelengths.

High Intensity Discharge (HID): A lamp that produces light by establishing an arc between two electrodes located a few inches apart in opposite ends of of a small, sealed, translucent or transparent arc tube. The arc of electricity generates heat and pressure high enough to vaporize the atoms of various metallic elements contained within the arc tube. This vaporization causes the atoms to emit large amounts of electromagnetic energy in the visible range. The HID types include mercury, metal halide and high pressure sodium.

Table 3-7. General Lamp Source Performance Characteristics

Source	Luminous Power (Watts)	Efficiency (Maximum Lumen/ Watt)	Maximum Lumen Maintenance (% at end of life)	Life at Rated Voltage (hr)
Incandescent				
General service	40	11	80	1000-1500
	100	17	80	
Tungsten-halogen	500	20	94	2000-4000
Fluorescent				
Type CW	20	45	90	9000
Type CWX	20	28	90	9000
Type CW	40	64	90	18000+
Type CWX	40	44	90	18000+
High Intensity Discharge				
Deluxe white mercury	100	33	75	24000+
	250	38	75	24000+
Metal halide	400	63	50-55	7500
High pressure sodium	400	92	85	6000

Table 3-8. Lamp Source Evaluation

Source	Evaluation
Incandescent - general service	Source is strong in the red end of spectrum (longer wavelengths), weak in the blue end of the spectrum; color acceptance is excellent; flattering to skin tones.
	Compact source lending itself to optical systems and projection
	Available in any wattage and physical size and shape
	Brightness is readily controlled over infinite range by simple voltage control (dimmer).
	Operates on DC or AC (any frequency) equally well
	Susceptible to shock and vibration (filament sagging or shorting)
	Relatively insensitive to operating environment temperature
	Vibration and rough service lamps are available. Additional filament supports cool filament temperature and reduce luminous efficacy.
	No radio interference with equipment
	No hazard other than broken glass; no mercury contamination (Lamps available with protective non-shattering plastic coating)
	Available in most common voltages
	Excellent heat source
Incandescent - tungsten-halogen	Same evaluation as for general service except as follows:
	No bulb blackening due to tungsten-halogen cycle. Bulb temperature must be maintained at 250°C minimum temperature for cycle to operate. Lamp (long, linear filament types) must be operated within 4° of horizontal; not a necessary limitation with short, compact filament types.
	Available in double-ended, linear bulb configuration; increasing expansion of product line includes jacketed lamps, reflector lamps, and compact source lamps that can be operated in any position.
	Slight danger to UV radiation (quartz envelope) especially when operated at over-voltage or high color temperature
	More rugged than general service lamps due to additional filament supports

Table 3-8. Lamp Source Evaluation (continued)

Source	Evaluation
Fluorescent	Requires auxiliary equipment (ballast) for starting and limiting of lamp current
	Range of colors available is excellent. Standard cool white and warm white lamps have very good color acceptance although object colors tend to have a washed out appearance. Skin complexions can be sallow. Excellent color rendition can be achieved with deluxe color lamps at the expense of approximately 30% reduction in luminous output.
	Lamp is long, linear, low brightness source which does not lend itself to optical systems or projection. Lamp brightness must still be shielded for glare control.
	DC operation is possible but limited by polarization of lamp and relative inefficiency of current limiting device (ballast). Development of solid-state inverters has allowed efficient operation of fluorescent lamps from DC supplies. Low voltage systems are available on same basis.
	Operation at high frequency results in improved luminous efficacy. Ballast size and weight are reduced.
	Possible mercury contamination if lamp envelope would break.
	Dimming is possible with properly designed auxiliary equipment although not as flexible and reliable as incandescent dimming.
	Some minor amounts of UV radiation; glass envelope contains most. Special composition glass envelopes are available for passing UV radiation for photo-biological needs if required.
	Fluorescent lamps are very sensitive to ambient temperature changes with light falling off with either increased or decreased temperatures from optimum.
	Electrodes are fairly rugged and resistant to shock and vibration.
	Possible radio-frequency interference with sensitive equipment (eliminated in proper shielding of lamp and filtering of power supply)

Table 3-8. Lamp Source Evaluation (continued)

Source	Evaluation
High Intensity Discharge - mercury vapor	Requires auxiliary equipment (ballast) for starting and operation
	Clear lamp is excellent compact source for optical systems and projection but color is unacceptable due to blue-green appearance (lack of red color). Phosphor coated lamps (specifically, Deluxe White) have color rendition comparable or slightly better than Standard Cool White fluorescent, but phosphor coating increases the source size significantly to reduce its efficiency in optical and projection systems.
	Extremely rugged construction
	Cannot be dimmed
	DC operation would require solid-state inverter systems. Straight DC operation would require special lamp construction to avoid polarization of lamp electrodes.
	Operation at higher frequencies results in higher efficacies; however, at certain frequencies standing waves occur in the arc tube which extinguish the arc.
	Momentary power interruption results in lamp being extinguished (10-15 minutes required before lamp will restrike). Auxiliary incandescent or fluorescent sources would have to be available during this period.
	Double-jacketed lamp construction filters out most, if not all, UV radiation. Lamp is insensitive to ambient temperature variations, although extremely low temperature operation would require special low temperature ballast for starting.
	Mercury contamination would be a problem.
	RF interference might be a problem with certain types of electronic equipment (could be screened without much effort).
HID Metal Halide and High Pressure Sodium (additional comments)	Momentary power interruption results in the lamp being extinguished. The high pressure sodium lamp restrikes within several minutes; the metal halide lamp within 10-15 minutes.
	The high pressure sodium lamp requires a special high voltage (20,000 v) surge for starting purposes. This is provided by a special circuit within the ballast housing.

Table 3-8. Lamp Source Evaluation (concluded)

Source	Evaluation
HID Metal Halide and High Pressure Sodium (additional comments) [continued]	Available only in higher wattages Reliability of performance has not been as well established as with mercury vapor and fluorescent lamps. Both are clear jacketed lamps having small compact arc tubes that lend themselves to optical systems and projection. Color rendition of the metal halide lamp is very good. The high pressure sodium lamp has a definite yellow or golden appearance which might bother some people in interior applications.

Table 3-9. Lamp Source Evaluation Summary

	Incandescent - General Service	Incandescent - Halogen Cycle	Fluorescent - Standard Colors	Fluorescent - Deluxe Colors	Mercury Vapor - Deluxe White - HID	Metal Halide High Intensity Disch.	High Pressure Sodium - HID
Efficacy, lms/watt	5	4	1	2	2	1	1
Life, rated	5	4	1	1	1	3	3
Color							
Acceptable	1	1	2	1	2	2	4
Flattering	1	1	3	1	3	2	5
Color rendering	1	1	3	1	3	2	5
Optical Characteristics							
Point source	1	1	5	5	3	1	1
Large source, low brightness	5	5	1	1	3	5	5
Projection	1	1	5	5	3	1	1
Appearance							
Warm	1	1	1	1	4	4	1
Cool	5	5	1	1	1	1	5
Luminaire Characteristics							
Auxiliary equipment	1	1	4	4	5	5	5
Size	1	1	5	5	3	2	2
Weight	1	1	4	4	5	5	5
Lumen Depreciation	2	1	2	3	4	4	1
Costs							
Initial	1	1	2	3	4	5	5
Operating	5	5	1	2	2	3	4
Ruggedness	5	4	2	2	1	2	2
Effects of ambient conditioning	1	1	5	5	1	1	1

Rating Scale

1 - Optimum
2 - Acceptable
3 - Some Compromise
4 - Undesirable
5 - Unacceptable

Table 3-10. Luminaire Types

Luminaire	Description
Recessed	Mounted above ceiling or behind a wall or other surface with the opening of the illuminaire level with the surface
Surface Mounted	Mounted directly on the ceiling or surface
Pendant Mounted	Mounted on an extension type structure
Cone	Comprises light sources shielded by a ledge or recess that distributes light over the shield (example: over the ceiling and upper wall)
Luminous Ceiling	Ceiling area lighting system comprising a continuous surface of transmitting material of a diffusing or light controlling character with light sources mounted above it
Retractable	Lighting which can be maneuvered for localized needs
Portable	Mobile-type lighting for localized needs

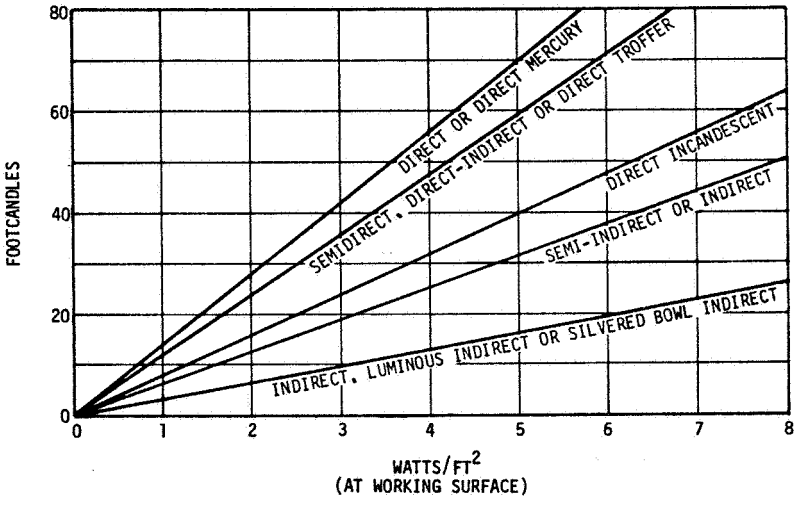


Figure 3-1. Luminaire Type - Footcandles vs Watts

Table 3-11. Evaluation of Luminaire Systems

Luminaire System	Merits	Deficiencies
Recessed Lighting	Luminaires flush with room surfaces, no dangerous projections. Sealed units to minimize dirt depreciation. Available in combination air handling units. RF interference can be effectively shielded.	Generally provide little light on ceiling to minimize brightness contrasts. Maintenance from room below might be difficult. Requires space above plane of ceiling.
Surface Mounted Lighting	Requires no space above plane of ceiling. Can provide light on adjacent ceiling to help improve comfort. Easy maintenance. RF interference can be effectively shielded.	Appearance may be objectionable (not a clean look). Cannot be combined with air handling equipment.
Pendant Mounted Lighting	Maximum utilization of light from luminaire. Lends itself to indirect lighting. Minimizes temperature problems within luminaire.	Not feasible in low ceiling areas. Possible dangerous projections within room. Cannot be combined with air handling functions.
Cove Lighting	May be one of most effective. Can be very comfortable.	Minimal design information is available.
Luminous Ceilings	Low brightness and excellent uniformity of lighting levels.	Excellent illumination but very bland and uniform. Might be too expensive.
Retractable Lighting	Combines advantages of suspended and recessed lighting. Excellent for placing localized lighting where needed.	Greater maintenance problems. Expensive. Additional weight of retracting mechanism.
Portable Lighting	Excellent for localized lighting.	Provide means for securing in position. Power cord necessary.

Table 3-12. Light Loss Causes

Cause	Remarks
Lamp Lumen Depreciation	As shown in Table 3-7, there is a normal loss of light output as the lamp source ages. To maintain the desirable level, the design footcandle level should be increased to allow for this aging.
Luminaire Dirty	As luminaires become dirty, their reflectance characteristics are decreased. This prevents the proper designed light distribution about the environment.
Lamp Outages	As shown in Table 3-7, there is a definite life of a lamp source. This aging is a maintenance problem which must be considered for both replacement and disposal.
Luminaire Surface Deterioration	As luminaire surfaces deteriorate, less light is reflected, thus preventing light distribution as originally designed.
Room Surfaces Dirty	As surfaces become dirty, their reflectances are changed. This causes variation of light distribution with the original design.
Temperature and Voltage Variations	Variation in voltages can change the operating temperature of a lamp source. This can cause variations in color output of the lamp that changes the illumination levels.

People are emotionally responsive to their surroundings, and color is one of the chief characteristics of those surroundings. Every light source produces light of distinctive color (spectral) characteristics. Therefore, the type of light source under which the colors are ultimately to be seen should be used when colors are being selected or compared for any purpose.

3.1.3.8 Crew Area Factors in Lighting. Table 3-13 provides various crew area requirements in lighting.

3.1.4 Lighting Effects.

3.1.4.1 Moods. First impressions of rooms have to be positive to provide the proper incentive and to encourage optimum performance. Table 3-14 indicates the various moods created by lighting.

3.1.4.2 Emphasis. Means of creating architectural emphasis in lighting are provided in Table 3-15.

Table 3-13. Crew Area Lighting Requirements

Crew Area	Requirements
Public Areas (Relaxation) - Includes: Lounge, Snack Bar, Recreation Room, Gym, Locker Room, Chapel, and Dining Room	Visual tasks are not critical. Prime emphasis is on relaxation, change of pace lighting. Lighting must have capability of being adjusted or varied. Localized lighting for creating visual centers. Lighting levels should match activities. Deluxe colors are desirable.
Public Areas (Work) - Includes: Communications, Computer, Control Room, Briefing Room, Library, Offices and Laboratories	Visual tasks are of a critical nature. Lighting levels must be based on effective footcandles which can be measured in actual situation (prototype). Lighting must have subtle variations from space to space. Localized lighting should be provided to increase levels on severe visual tasks and to create visual centers. Deluxe color lamps enhance visual interest.
Living Areas - Includes: Bedroom, Bathroom and Study Room	Visual tasks may or may not be of critical nature. Lighting colors should be flattering and relaxing. Good lighting is essential for personal hygiene. Lighting should be adjustable to individual tastes and requirements.
Transition Areas - Includes: Passageways, Halls, Stairs, Elevators, Air Locks and Dock	Lighting must provide smooth transition between areas both in lighting levels and colors. Lighting must be adequate.
Service Areas - Includes: Kitchen, Barbershop, Dispensary, Laundry, Photographic Support, Shops, and Inspection	General lighting must provide sufficient levels with supplementary lighting for specific visual tasks of severe nature. Lighting is functional in concept with attention given to maintenance. Deluxe color sources may be critical in specific applications. Lighting is for safety of operations in each area.
Maintenance Areas - Includes: Supply, Power, Maintenance, Storage and Equipment	Lighting levels are generally minimal with supplementary lighting for critical tasks. Emergency lighting must be available in power and equipment areas. Equipment and areas should be color coded for safety.
Agricultural Areas	Lighting levels must be adequate for hygiene and safety. Control must be provided for creating time-light cycles.

Table 3-14. Moods in Lighting

Mood	Lighting
Gaiety	Higher levels of illumination with color and movement. Changing effects of color and changes in illumination should not be sudden, but should be smooth and stimulating.
Solemnity	Subdued patterns of light with emphasis at dramatic points. Color should be used sparingly and with atmospheric effect. Changes of illumination should be imperceptible.
Restfulness	Low brightness patterns, no visible light sources, subdued color, dark upper ceiling, and a low wall brightness, decreasing upward to the ceiling.
Activity	Higher levels of illumination, with proper local lighting for the more difficult visual tasks.
Warmth	Colors at the red end of the spectrum: red, red-orange, orange, yellow, amber, gold and pink.
Coolness	Colors at cool end of spectrum, such as blue, blue-green, green, magenta, violet. These colors mixed with white produce various cool tints.

Table 3-15. Architectural Emphasis by Lighting

Emphasis on Increasing	Lighting Pattern
Height	Verticle lighting patterns from floor to ceiling
Width	Accentuate lines of light across room, on both walls and ceilings
Length	Use lighting lines that give perspective such as parallel, longitudinal lines

3.1.5 Sample Calculations. Examples of the basic calculations used in determining the number of luminaires necessary to achieve a given illumination level are shown below. The influence each factor in the equation plays in the final determination of the required number of luminaires is of primary importance. Two methods are presented: the lumen method that is generally used in determining the average illumination within the room; and the point-by-point method which is used to determine the illumination at a specific point due to one or more luminaires.

3.1.5.1 The Lumen Method.

$$\text{No. of Luminaires} = \frac{E \times \text{Area}}{(\text{No. of Lamps/Luminaire})(\text{Lumens/Lamp})} \times \frac{1}{(CU)\ (LLD)\ (LDD)}$$

where:

E = Maintained footcandles

Area = Area in square feet of the working surface; typically room width x room length

No. of Lamps/Luminaire is obtained from luminaire description.

CU = Coefficient of Utilization; the percentage of light leaving a luminaire and eventually reaching the working surface either directly or through interflections. Luminaire manufacturers provide this information in tabular form for their equipment. The CU table is calculated from photometric data of the luminaire.

LLD and LDD = Lamp lumen depreciation and luminaire dirt depreciation. Taken together these two factors relate initial footcandles to maintained footcandles. This information may come from the manufacturers' catalogs or from typical data presented in the 4th Edition of the IES Lighting Handbook, pages 9-16 and 9-17.

The lumens per lamp or luminous efficacy of the light source plays a direct part in determining the number of luminaires. A high efficacy source, such as the fluorescent lamp, would require fewer luminaires, and consequently, lower power requirements than a lower efficacy source, such as the incandescent lamp.

The lamp lumen depreciation factor (percent of initial lumens produced at 70 percent of rated life) varies with the type of light source. Typical values for several different sources are:

General service incandescent	90%
Tungsten-halogen incandescent	95%
Phosphor coated mercury	75-83%
Fluorescent	
Standard Colors	86%
Deluxe Colors	80%

Dirt depreciation factors for luminaires also varies with the type of luminaire (open or enclosed), the cleanliness of the environment, and the maintenance schedule. Typical factors for most luminaires are given in the IES Lighting Handbook.

The CU for a luminaire is perhaps the one most significant figure in determining the overall performance of a luminaire. It is directly related to the luminaire's efficiency and it takes into account the light distribution and transmittance of the luminaire's shielding. Computations based on the interflections of radiant energy within enclosures are used in deriving the CU tables. These computations are performed by the fixture manufacturer from the photometric data of the luminaire according to the IES standardized procedure known as the Zonal Cavity Method. The CU tables are calculated for various room sizes and surface reflectances.

To enter the CU table one must calculate a Room Cavity Ratio. This technique mathematically determines equivalent room configurations from the actual room dimensions and allows standardization of the CU tables.

$$\text{Room Cavity Ratio} = \frac{5\ h_r\ (\text{Room Length} + \text{Room Width})}{(\text{Room Length} \times \text{Room Width})}$$

where: h_r = height of room cavity from the working plane to the plane of the luminaires

$$\text{Ceiling Cavity Ratio} = \frac{5\ h_c\ (\text{Room Length} + \text{Room Width})}{(\text{Room Length} \times \text{Room Width})}$$

where: h_c = height of ceiling cavity from the luminaire to the ceiling. With a totally direct light distribution, h_c = 0 for recessed or surface mounted luminaires.

$$\text{Floor Cavity Ratio} = \frac{5\ h_f\ (\text{Room Length} + \text{Room Width})}{\text{Room Length X Room Width}}$$

where: h_f = height of floor cavity from the floor to the working plane, normally 2-1/2 feet.

From these ratios and the reflectances of the room surfaces, one can determine the effective ceiling and floor reflectances from tables in the IES Lighting Handbook, page 9-4. Having determined these effective reflectances, one can then enter the CU table to determine the proper value to use in the illumination calculation formula. Although the method seems cumbersome, it is straight-forward in its application. The Zonal Cavity Method allows greater flexibility and accuracy in making these illumination calculations than previous systems.

Ceiling and wall luminance tables are also available which are very similar in appearance and used as the CU tables. These luminance tables are important in determining brightness ratios within a room from the luminaire data.

3.1.5.2 Point-by-Point Method. The point-by-point method of illumination calculations is used when it is necessary to know the illumination at a specific point from a limited number of luminaires. It is not generally used for determining average lighting levels in a room. It is used for calculating the illumination from supplementary sources used to increase the lighting levels in localized areas.

The basic formula is the inverse square law:

$$E = \frac{I \cdot \cos\theta}{D^2}$$ for horizontal surfaces

$$E = \frac{I \cdot \sin\theta}{D^2}$$ for vertical surfaces

where:

E = the illumination at a particular point.

I = the candlepower intensity of the luminaire in the direction concerned.

Θ = the angle between the luminaire and the point for which the illumination is being calculated. It is measured as the verticle angle, 0° being directly below the luminaire. This candlepower data is obtained from the photometric data on the luminaire.

D = The distance from the luminaire to the point for which the illumination is being calculated.

Illumination values calculated by this formula are additive. When several luminaires are involved, the illumination resulting from each is added directly to determine the illumination total. This method does not take into account interflected light.

3.2 ACOUSTICS

3.2.1 Requirements. In an extraterrestrial environment, men will be confined in a limited volume habitat for relatively long periods of time. Therefore, particular attention must be given to acoustics to insure the safety, well-being, and optimum performance of the occupants. High intensity sound can produce temporary or permanent damage to the ear, interfere with communications and interfere with the performance of critical tasks. Conversely, the oppressive quality of the absence of sound can be as exhausting as excessive noise stimulation.

In order to determine whether a particular noise environment is likely to be detrimental or hazardous, the designer must compare the characteristics of the acoustical environment with the applicable criteria (damage risk, communications, annoyance, etc.). To make such a comparison the designer needs to know:

- The sound pressure level and spectrum of the noise
- The type of noise (wide band, pure tone, or impulsive)
- The duration and nature of the exposure (continuous, intermittent, etc.).

When the comparison results in an unfavorable acoustical environment, suitable noise control techniques must be implemented to correct this condition.

3.2.2 Definitions.

Absorption Coefficient - The sound-absorption coefficient of a surface which is exposed to a sound field is the ratio of the sound energy absorbed by the surface to the sound energy incident upon the surface.

Acoustics - The science of sound

Articulation Index - A predictive measure of speech intelligibility. Formulation of the articulation index is based on the fraction of the total speech band-width to the listener's ear and the signal-to-noise ratio at the listener's ear.

Attenuation - Attenuation is the term used to express the reduction in decibels of sound intensity at a designated point A as compared to sound intensity at point B which is acoustically farther from the source.

Acoustic Impedance - The complex ratio of the effective (rms) sound pressure over a surface to the effective volume velocity through it.

Characteristic Impedance ($\rho_0 C$) - The ratio of the effective sound pressure at a given point to the effective particle velocity at that point in a free, plane, progressive wave.

Dynamic Range (of speech) - Difference, in decibels, between the pressure level at which overload occurs (according to some overload criterion) and the pressure level of the noise of the system.

Decibel - The decibel is a dimension used for expressing the ratio of two powers and is referred to a reference level of 0.0002 dynes per square centimeter. Mathematically, the number of decibels is 10 $\log_{10}$ of the power ratio. Since sound pressure is proportional to the square root of sound power, the number of decibels in sound pressure level ratios is expressed as 20 $\log_{10}$ of the ratio of the two sound pressures.

Energy Density - The average energy per unit volume in a medium due to the presence of a sound wave.

Free-Field - A field in which the effects of the boundaries are negligible over the region of interest.

Frequency - The rate of repetition in cycles per second of the sound wave. Frequency is equal to the ratio of the speed of sound to the wave length of sound. It is normally expressed as Hertz (Hz).

$$\text{Approximate frequency} = \frac{\text{speed of sound}}{\text{wave length of sound}}$$

Hearing Loss - Hearing loss is the difference in decibels between the threshold of audibility for that ear and the normal threshold of audibility at the same frequency.

Intensity - The average rate at which sound energy is transmitted through a unit area perpendicular to the direction of wave propagation. A decibel scale of sound intensities is indicated in Figure 3-2.

Intensity Level - Ten times the logarithm to the base 10 of the intensity under consideration to the reference intensity.

Microbar - A unit of pressure commonly used in acoustics. One microbar is equal to one dyne per square centimeter.

Noise - Noise is any undesired sound. As used broadly in acoustics, this may include not only aircraft noise and industrial sounds, such as traffic and machinery, but also speech and musical sounds if they are undesired at any particular location.

Phon - A unit of loudness level. The loudness level of any sound is defined as the sound pressure level of a 1000 Hz tone that sounds as loud as the sound in question.

Preferred Frequency Speech Interference Level (PSIL) - The average in decibels of the sound pressure levels of a noise in the three octave bands of frequency centered at 500, 1000, and 2000 Hz.

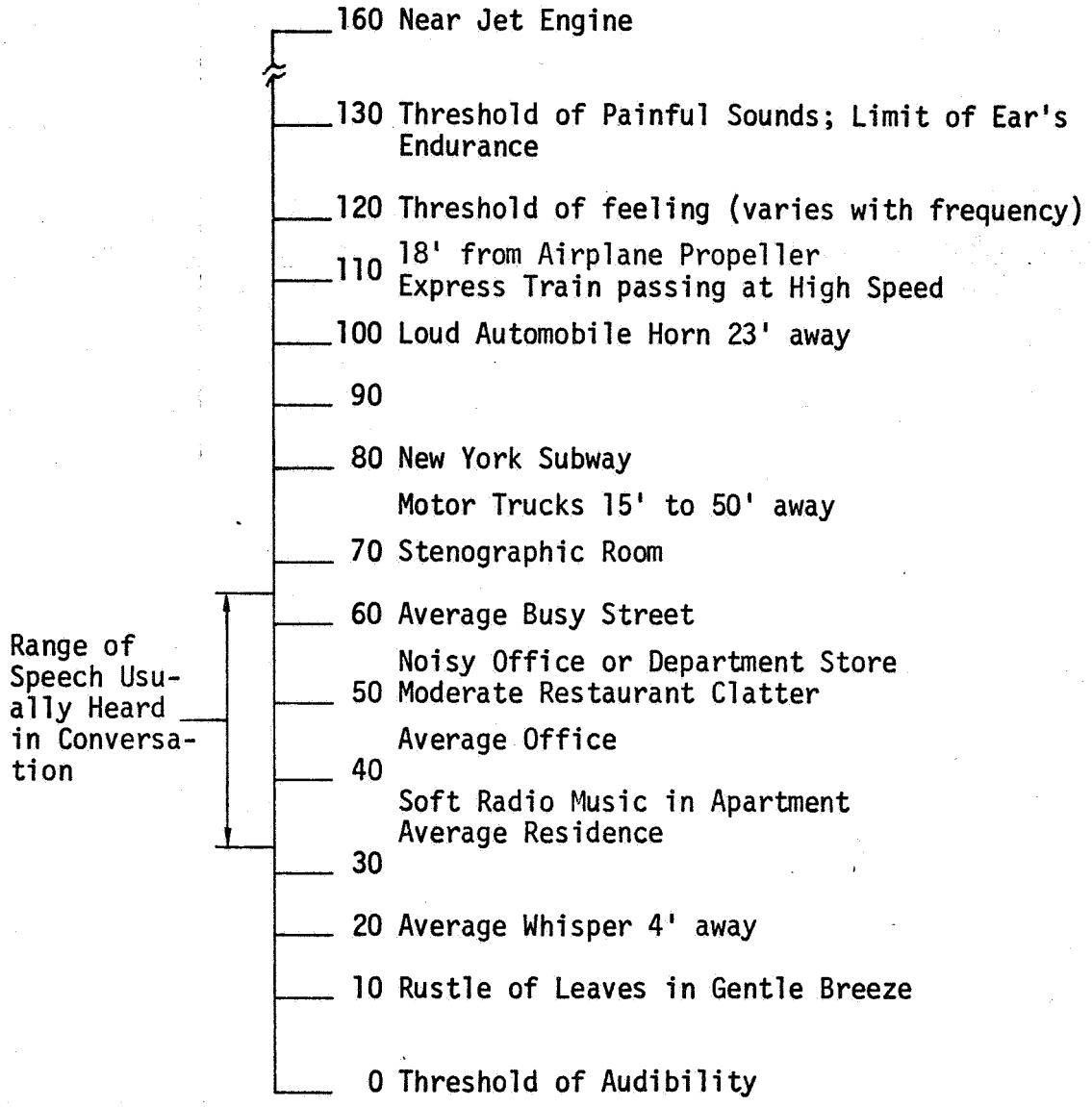


Figure 3-2. Decibel Scale of Sound Intensities

Reverberation Chamber - An enclosure in which all the surfaces have been made as sound reflective as possible.

Reverberation Time - The time required for the average sound pressure level, originally in a steady state, to decrease 60 dB after the source is stopped.

Sound Power Level (PWL) - A computed quantity which expresses the acoustic power of a sound source relative to a reference power.

Sound Pressure Level (SPL) - Twenty times the logarithm (to the base 10) of the ratio of a sound pressure to the reference pressure.

Speech Interference Level (SIL) - The speech interference level of a noise is the average in decibels of sound pressure levels of a noise in the three octave bands of the frequency 600-1200, 1200-2400, and 2400-4800 Hz.

Specific Acoustic Impedance - The complex ratio of the effective sound pressure at a point of an acoustic medium to the effective particle velocity at that point.

Spectrum - Spectrum is the composition of the frequency distribution of a sound wave. In noise survey work, the spectrum of primary importance includes frequencies from 20 to 10,000 cycles per second. For the purpose of presenting damage risk, speech interference, and nuisance levels, the spectrum is broken down into eight octave bands.

Threshold of Audibility - The threshold of audibility for a specified signal is the minimum effective sound pressure of the signal that is capable of evoking an auditory sensation in a specified fraction of the trials.

Temporary Threshold Shift - A shift in the threshold of audibility after exposure to even a moderate noise level.

Transmission Loss - Transmission loss is the ratio expressed in decibels of the sound energy incident on a structure to the sound energy which is transmitted through it. The term is applied both to building structures, such as walls and floors, as well as to air passages, such as mufflers and ducts.

Sound Waves - Sound waves can be described by any of several characteristics, such as the displacement of particles of the medium, the particle velocity, or the sound pressure measurements under certain conditions. The passage of a sound wave is accompanied by a flow of sound.

3.2.3 Engineering Data.

3.2.3.1 Frequency.

3.2.3.1.1 Pure-tone vs Wide-band Noise - A pure-tone noise is predominantly made up of pure frequency components such as propellor noise, compressor whine, and sirens. In wide-band noise the acoustical energy is spread throughout the spectrum. In most cases, especially within aerospace vehicles, the noise is a combination of pure-tone and wide-band noise. Since there are different criteria for each case, the designer must decide whether the noise is predominantly pure tone or wide band. A practical rule of thumb is that, if the OB SPL in a band is more than 3 dB above the adjacent bands, the noise is pure tone or has narrow-band components.

3.2.3.1.2 Frequency Bands - Electrical filters are normally used for analyzing noise. These filters reject signals of frequency below a lower "cutoff" frequency and above the upper "cutoff" frequency. Signals between these two frequencies are passed by the filter; this intermediate region is referred to as the passband. The difference between the cutoff frequencies is normally referred to as the bandwidth.

Until recently, passbands usually included in filters intended for noise measurement used the frequency ranges listed in Table 3-15.

Table 3-15. Octave Band Frequency Ranges

Frequency (Hz)		
Lower Cutoff	Upper Cutoff	Center
37.5	75	53
75	150	106
150	300	212
300	600	425 } *
600	1200	850 } *
1200	2400	1700 } *
2400	4800	3400
4800	9600	6800

* Average of these three bands equals the SIL.

When more detailed information about a noise spectrum is required, third-octave bands are normally used. These bands are one-third the range of the octave bands. The standard set of 1/3 octave bands used by the Acoustical Society of America is indicated in Table 3-16.

In order to make the octave bands consistent with the accepted 1/3 octave band values indicated in Table 3-16, a new set of octave band preferred frequencies for acoustical measurements has recently been set forth as A.S.A. Standard S-1.6 - 1960. The standard octave bands fit the ratio $f_h/f_l = 10^{0.3} = 1.9952$. The values are indicated in Table 3-17.

Table 3-16. One Third Octave Bands

N	Mean Frequency (Hz)	Bandwidth Cut-off Frequencies (Hz)		Bandwidth Frequency (Hz)
4	2.5	2.2	2.8	0.6
5	3.1	2.8	3.5	0.7
6	4.0	3.5	4.4	0.9
7	5.0	4.5	5.6	1.1
8	6.2	5.6	7.0	1.4
9	8.0	7.0	8.8	1.8
10	10.0	8.9	11.2	2.3
11	12.5	11.1	14.0	3.0
12	16.0	14.0	17.5	3.5
13	20.0	17.5	22.0	4.5
14	25.0	22.3	28.0	5.7
15	31.5	28.0	35.0	7.0
16	40	35.7	44.9	9.0
17	50	44.6	56.1	11.5
18	63	56.2	70.7	14.5
19	80	71.3	89.8	18.5
20	100	89.1	112.2	23.1
21	125	111.4	140.3	29
22	160	142.6	179.5	37
23	200	178.2	224.4	46
24	250	222.8	280.5	58
25	315	280.7	353.4	72
26	400	357	448.8	92.3
27	500	446	561.0	115
28	630	562	706.9	145
29	800	713	897.6	185
30	1000	891	1122	231
31	1250	1114	1403	288
32	1600	1426	1795	369
33	2000	1782	2244	462
34	2500	2228	2805	577
35	3150	2807	3534	727
36	4000	3565	4488	923
37	5000	4456	5610	1154
38	6300	5615	7069	1454
39	8000	7130	8976	1846
40	10000	8912	11220	2808
41	12500	11140	14030	2880
42	16000	14260	17950	3890
43	20000	17820	22440	4320
44	25000	22280	28050	5770
45	31500	28070	35340	7270
46	40000	35650	44880	9230
47	50000	44560	56100	11540

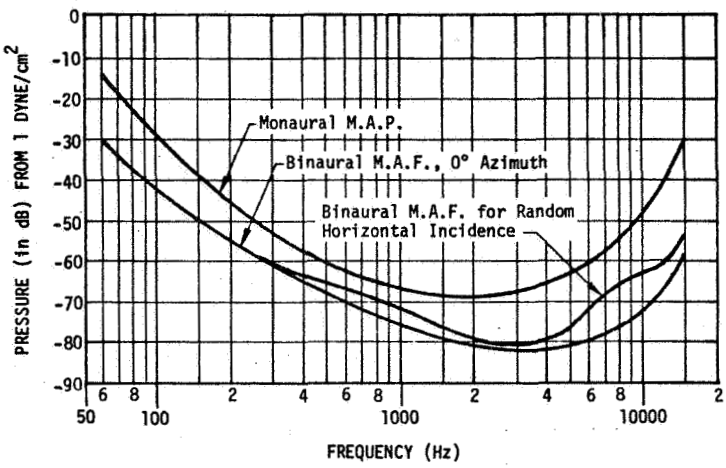
Mean Frequency = $10^{0.1\ N}$

Table 3-17. Standard Octave Band Frequencies

Frequencies (Hz)		
Lower	Upper	Center
11.2	22.4	16
22.4	44.7	31.5
44.7	89.2	63
89.2	178	125
178	355	250
355	709	500
709	1410	1000
1410	2820	2000
2820	5630	4000
5630	11200	8000
11200	22400	16000

3.2.3.1.3 Hearing - The range of hearing for people is of considerable interest. Tests have indicated that some people can hear sounds at frequencies as low as 2 Hz; however, at that frequency a sound pressure level of approximately 135 dB would be necessary to produce audibility. The upper limit of hearing is quite variable. Tests have shown that young people may hear up to 20,000 Hz if the tone is intense enough. This upper limit tends to decrease as people age, with middle aged people usually being able to hear only up to 12,000 to 16,000 Hz. However, the level at which the tone is presented is important in determining these upper and lower limits.

The auditory response to the frequency of pure tones is commonly accepted as falling between about 16 Hz and 20,000 Hz as indicated in Figure 3-3.



NOTE: M.A.P.=Minimum Audible Pressure
M.A.F.=Minimum Audible Field

Figure 3-3. Absolute Thresholds for Reception of Signals

The limits for response to intensity vary as a function of frequency. They are often different for different individuals and the threshold may vary from time to time in the same individual. The limits for response to intensity extend from the minimum level (i.e., absolute threshold) at which a sound can be heard to intensities where feeling and discomfort begin. The minimum intensities to which the ear will respond vary as much as 80 dB with the greatest sensitivity between 2000 and 4000 Hz. Individual differences in absolute thresholds vary as much as 20 dB and can vary as much as 5 dB within a short period of time.

The audibility of a signal depends on the duration since the response of the ear is not instantaneous. For pure tones, about 200-300 milliseconds are required for buildup and approximately 140 milliseconds to decay. Thus, tones of less than 200-500 milliseconds do not sound as loud and are not as audible in noise background as sounds of longer duration.

3.2.3.1.4 Speech - Four curves relating sound-pressure level to frequency are shown in Figure 3-4. Curve A shows, for each frequency band of 1 Hz width, the instantaneous pressure that was exceeded in only 1 percent of the 1/8-second intervals. This curve is, in a sense, a "peak-instantaneous-pressure" curve. Curve B shows, for each frequency band, the

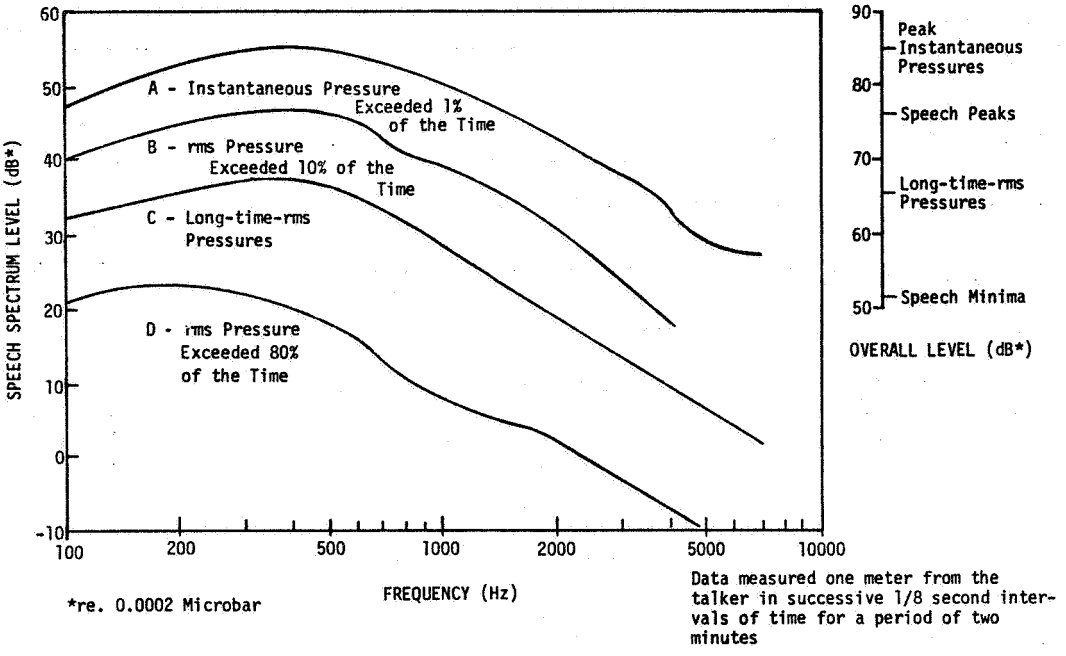


Figure 3-4. Spectrum Level of Instantaneous and RMS Pressure of Speech

root-mean-square (rms) pressure that was exceeded in only 10 percent of the 1/8-second intervals. (This can be called the curve of "speech peaks".) Curve C is the long-time-rms pressure. Curve D shows, for each frequency band, the rms pressure that was exceeded in 80 percent of the 1/8-second intervals. Inasmuch as about one-fifth of ordinary conversational speech is dead time, this lowermost curve represents, in a sense, the rms pressure of the weakest sounds. (This is referred to as the "speech minima" curve.) At the right-hand side of the graph are represented the corresponding overall levels - the values for unanalyzed, unfiltered speech.

3.2.3.2 Sources.

3.2.3.2.1 Types - Sound and noise problems arise at several points in long-term space operations. These problems can be broadly categorized into three phases:

1) Launch and boost
2) Orbit and interplanetary cruise (experiment and life support items)
3) Entry and landing.

Noise sources during the launch and boost phase and entry and landing

phase include rocket engine noise and aerodynamic noise developed during exit and entrance through the atmosphere. The duration of exposure is usually of the order of a few minutes.

During orbit and interplanetary cruise conditions, the number and types of noise sources are dependent upon the mission requirements. Certain sources of noise are inherent in any mission requirement; for example, fans, motors, pumps and compressors associated with the environmental control systems, and teleprinters, intercomms, etc. associated with communications.

3.2.3.2.2 Audio Warning Signals - Auditory signals are often used as alarms and warning devices to call attention to an urgent situation that may require instant action. Table 3-18 summarizes the principal characteristics and special features of various types of auditory alarm and warning devices. Table 3-19 summarizes design recommendations for such devices. In selecting and designing signals for alarm and warning, use sounds with frequencies between 200 and 5000 Hz, since the normal human ear is most sensitive to this middle range. Auditory signals should be used for only a few of the most urgent warnings.

3.2.3.3 Masking Effects. Because few environments are free of noise, noise is usually a limiting factor in a signal-processing system. Design of a signal-processing system must separate signal from noise. Noise mixed with a signal tends to raise the threshold for hearing that signal above the threshold in quiet, or absolute threshold. This phenomenon is called masking, and the elevated threshold is known as the masked threshold.

3.2.3.3.1 Monaural (Pure Tone) Masking - The masking of a signal, basically a pure tone, by another pure tone must be determined experimentally. The masking thresholds of signals for various representative frequencies and amplitudes are depicted in Figure 3-5. These are based on monaural reception of signals and noise. It will be noted from these curves that the masking effect is greatest when the signal and noise are of similar frequencies and is greater for noise frequencies below the signal frequency than for noises above the signal frequency. At relatively high intensities however, the masked threshold of signals that are some integral multiple of the masking tone is raised more than the threshold of those signals having no harmonic relationship to the masking tone.

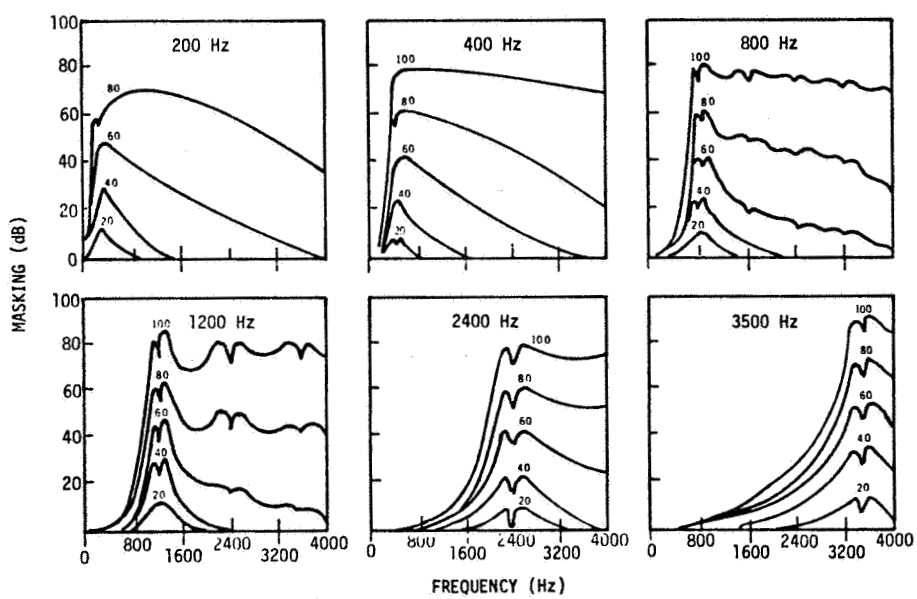
Table 3-18. Characteristics and Special Features of Various Alarms

Alarm	Intensity	Frequency	Attention-Getting Ability	Noise-Penetration Ability	Special Features
Diaphone (foghorn)	Very high	Very low	Good	Poor in low-frequency noise, good in high-frequency noise	
Horn	High	Low to high	Good	Good	Can be designed to beam sound directionally; can be rotated to get wide coverage
Whistle	High	Low to high	Good, if intermittent	Good, if frequency is properly chosen	Can be made directional by reflectors
Siren	High	Low to high	Very good if pitch rises and falls	Very good with rising and falling frequency	Can be coupled to horn for directional transmission
Bell	Medium	Medium to high	Good	Good in low-frequency noise	Can be provided with manual shutoff to insure alarm until action is taken
Buzzer	Low to medium	Low to medium	Good	Fair, if spectrum is suited to background noise	Can be provided with manual shutoff to insure alarm until action is taken
Chimes and Gong	Low to medium	Low to medium	Fair	Fair, if spectrum is suited to background noise	
Oscillator	Low to high	Medium to high	Good if intermittent	Good if frequency is properly chosen	Can be presented over intercom system

Table 3-19. Design Recommendations for Auditory Alarm and Warning Devices

Conditions	Design Recommendations
If distance to listener is great	Use high intensities and avoid high frequencies
If sound must bend around obstacles and pass through partitions	Use low frequencies (<500 Hz)
If background noise is present	Select alarm frequency in region where noise masking is minimal
To demand attention	Modulate signal to give intermittent "beeps" or modulate frequency to make pitch rise and fall at rate of about 1-3 Hz
To acknowledge warning	Provide signal with manual shutoff so that it sounds continuously until action is taken

In interaural masking (i.e., when the signal is fed into one ear and the noise into the other) no masking occurs when the noise SPL is relatively low (below 40 or 50 dB). When the noise SPL is above 50 dB, the sound is conducted through the bone of the skull to the opposite ear to produce masking as in the monaural case.



Note: Masking as a function of frequency for masking by pure tones of various frequencies and levels. Number at top of each graph is frequency of masking tone. Number on each curve is level above threshold of masking tone.

Figure 3-5. Masking of a Signal by Pure Tones

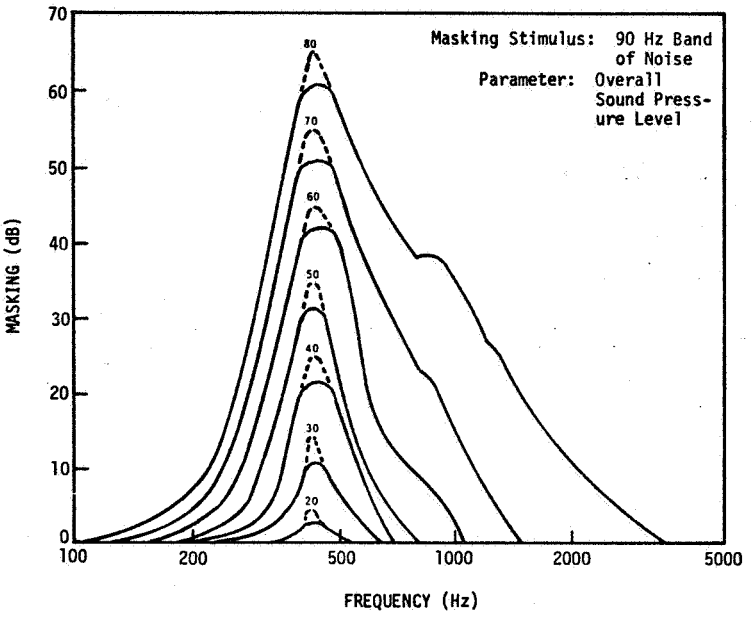
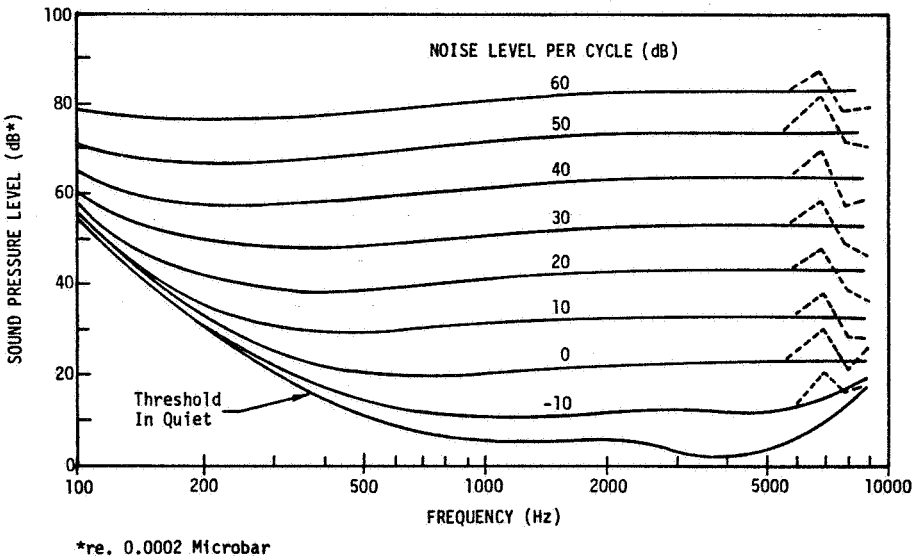


Figure 3-6. Masking of a Signal by Narrow-Band Noise



*re. 0.0002 Microbar

Figure 3-7. Masking of a Signal by Wide-Band Noise

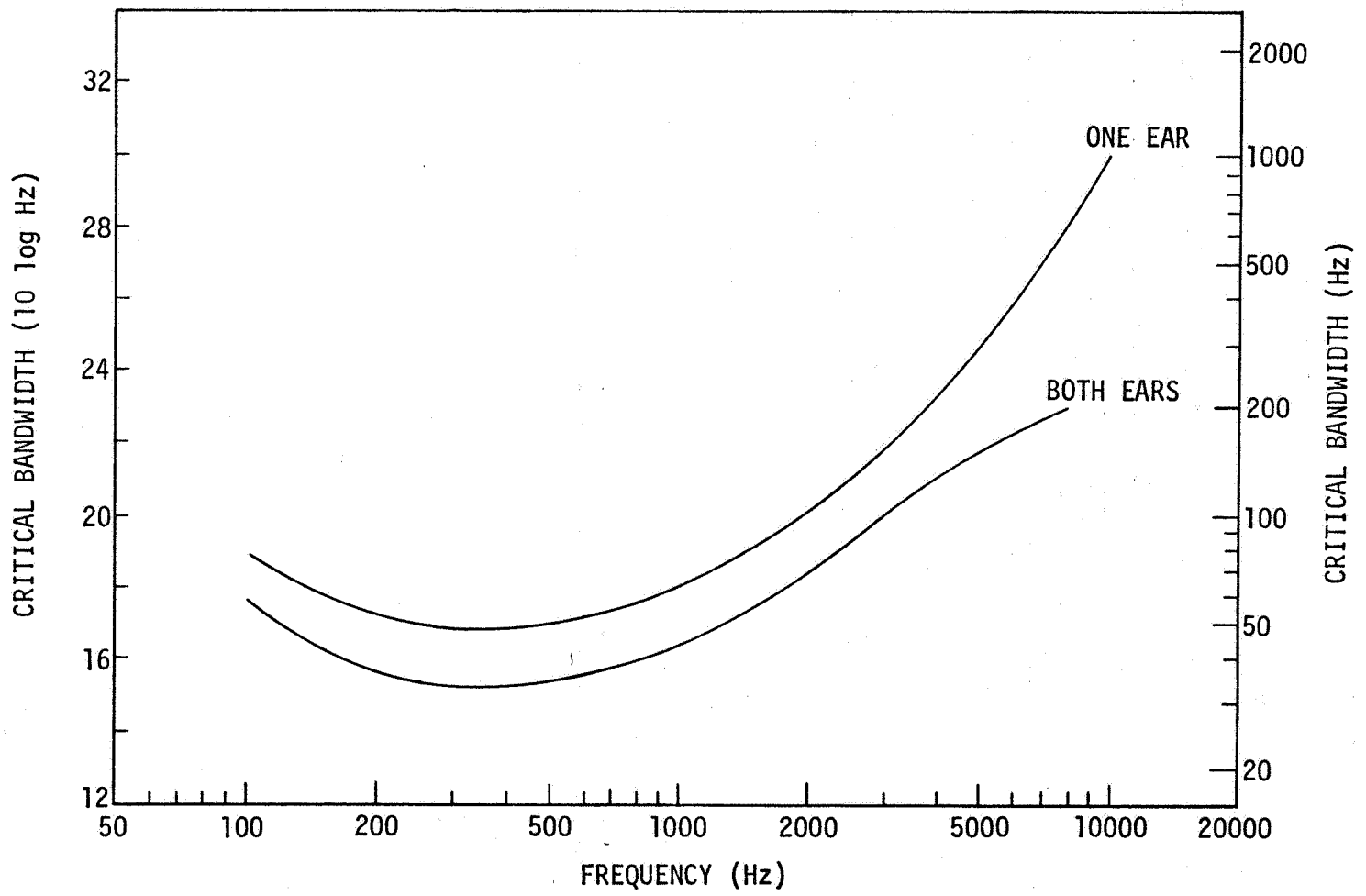


Figure 3-8. Critical Masking Bandwidth as a Function of Frequency

3.2.3.3.2 Narrow-Band Noise Masking - The masking of a signal by narrow-band noise is similar to those for pure tone masking except that the sharp dips caused by harmonics are absent. Figure 3-6 shows representative curves for monaural reception.

3.2.3.3.3 Wide-Band Noise Masking - Figure 3-7 shows the masked thresholds for a pure tone masked by wide-band noise of uniform spectrum (i.e., white noise). The amount of masking of a signal by wide-band noise can be predicted if the spectrum level of the noise is known at the frequency of the signal tone. In making such a prediction it is assumed that the masking is caused by noise frequencies which lie in a band near that of the signal. When used to predict masking, this critical band-width is so defined that the SPL of the noise in the critical ban is just equal to the SPL of the signal at its masked threshold. Figure 3-8 shows the generally accepted values of critical band-width as function of frequency.

The prediction of masking threshold at a given signal frequency (f) may be determined by measuring the spectrum level of the wide-band noise at the frequency of the signal. Correct this measured level to the level in the critical band at (f) by adding the 10 log of the critical band-width. This correction can be read directly from the left-hand ordinate in Figure 3-8. The corrected value is the masked threshold at (f) if the value is more than 20 dB above the absolute threshold at (f). If it is less than 20 dB, a correction must be made for non-linearity in the masking versus noise level function near the absolute threshold. To correct for masked threshold below 20 dB absolute threshold, use the curve in Figure 3-9.

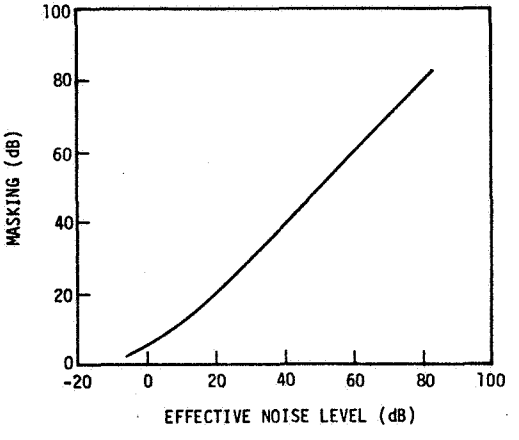


Figure 3-9. Masking in the Critical Band

3.2.3.4 Speech and Hearing.

3.2.3.4.1 Speech Intelligibility - A variety of criteria exist for determining whether an acoustical environment is suitable for auditory communication. One of the more useful of these criteria is the Speech Interference Level (SIL). In addition, the Articulation Index (AI) method of predicting speech intelligibility can and usually should be used to assess the effects of noise on speech communication.

3.2.3.4.2 Speech Interference Level - The speech inteference level (SIL) can be defined as the average, in decibels, of the SPL's of the masking (or interference) noise existing in the three octave bands, 600 to 1200, 1200 to 2400, and 2400 to 4800 Hz. The SIL provides a measure of the extent to which noise can interfere with the ability to communicate. The SIL method indicates the maximum noise level that will permit correct reception of 75 percent of phonetically balanced (PB) words or about 98 percent of test sentences. This criterion is equivalent to an AI of approximately 0.5.

To determine the SIL of a given noise spectrum, proceed as follows:

1) Measure the sound pressure level (in decibels) of the noise in octave bands 600 to 1200, 1200 to 2400, and 2400 to 4800 Hz.
2) Determine the arithmetic average of the decibel levels in the three octave bands. This average value is the SIL.

Figure 3-10 can then be used to obtain the maximum distance between the talker and listener at which 75 percent of PB words will be heard correctly. The use of SIL's in estimating speech interference is also indicated in Table 3-20.

3.2.3.4.3 Preferred Frequency Speech Interference Level (PSIL) - The PSIL method of specifying the speech interference aspects of noise is based on averaging octave band sound pressure levels centered at 500, 100, and 2000 Hz. This method was recently developed by comparing many known methods which equally measure speech - interfering noises, and relating these to the extensive validation studies of the older SIL. Since PSIL shows the smallest expected variability over diverse spectra noise and is simpler to measure with current acoustic acquisition equipment, it is becoming the recommended method of assessing the speech interference aspects of noise. To convert from SIL to PSIL, 3 dB can be added to the old SIL's.

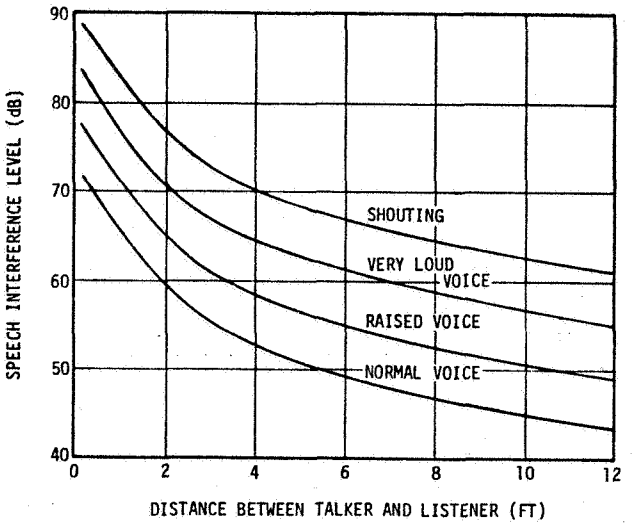


Figure 3-10. Speech Interference Levels

Table 3-20. Speech Communication Criteria

SIL dB	Voice Level and Distance	Nature of Possible Communication	Type of Working Area
45	Normal voice at 10 ft.	Relaxed conversation	Private offices, conference rooms
55	Normal voice at 3 ft; raised voice at 6 ft; very loud voice at 12 ft.	Continuous communication in work areas	Business, secretarial, control rooms of test cells, etc.
65	Raised voice at 2 ft; very loud voice at 4 ft; shouting at 8 ft.	Intermittent communication	
75	Very loud voice at 1 ft; shouting at 2-3 ft.	Minimal communication (danger signals, restricted prearranged vocabulary desirable)	

3.2.3.4.4 Articulation Index (AI) - The articulation index is a general criterion applicable for effects of noise on communication. The AI predicts the intelligibility of speech (i.e., the percentage of words or sentences which are correctly understood) for a specified noise environment.

Intelligibility depends on the type of message material or vocabulary. Three types of message material are generally used: (1) lists of

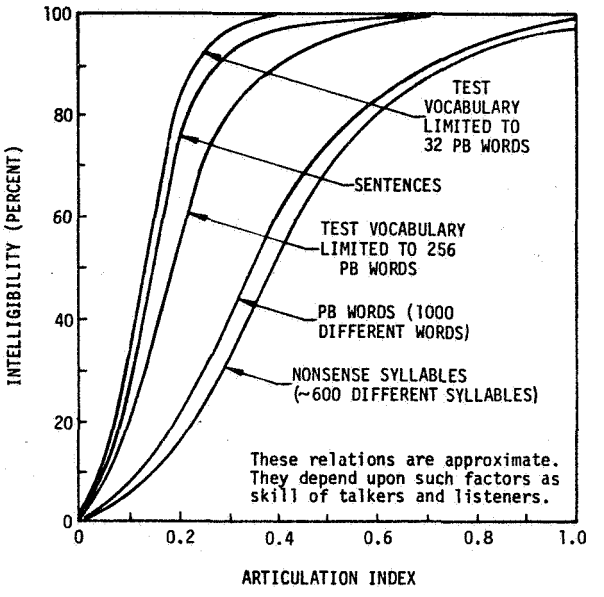


Figure 3-11. Intelligibility as a Function of the Articulation Index

nonsense syllables, (2) phonetically balanced monosyllable word lists, and (3) sentences. The relationship between intelligibility and the AI for various types of message material is indicated in Figure 3-11.

Two methods are available to determine the AI, referred to as the 20-band method and the weighted-octave-band (WOB) method. The 20-band method is more detailed and accurate, since it divides the frequency range of interest (200 to 6100 Hz) into 20 bandwidths. For wide-band noise, the WOB method may be used for noise with a smooth spectrum and for communication systems with no significant distortion. To compute an AI by the weighted average method, the following steps should be taken:

1) Draw a curve showing the speech spectrum level as a function of frequency on a chart similar to that shown in Figure 3-12. If there is no significant frequency distortion present in the communication system, use the octave-band speech spectrum indicated in Table 3-21.

2) Adjust the level to coincide with the level to be used in actual operation.

3) Draw a curve on the same chart showing the octave band levels of the noise.

Table 3-21. Octave-Band Spectrum of Speech

Octave Band	Speech Level (dB)* (re. 0.0002 microbar)
150-300	58
300-600	62
600-1200	58
1200-2400	52
2400-4800	46
4800-9600	40

*Overall speech level is 65 dB re. 0.0002 microbar (moderate voice)

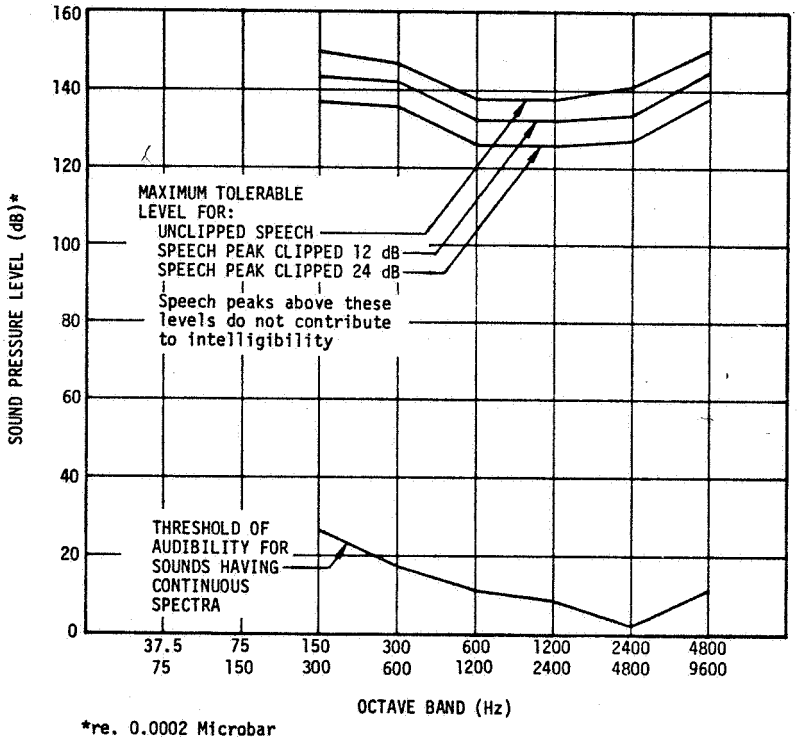


Figure 3-12. Articulation Index Computation Chart (Octave-Band Method)

4) At each octave band, measure the difference between the speech-peak level and the noise spectrum level. If in any octave band the noise level is below the threshold of audibility, use the threshold curve rather than the noise curve. If in any octave band the speech peak curve is above the appropriate limiting curves at the top of the chart, use that curve rather than the speech-peak curve.

5) Obtain the fractional contribution (W) of each octave by entering Figure 3-13 with the ratios of speech peaks to rms noise (or quiet threshold) in each indicated octave band.

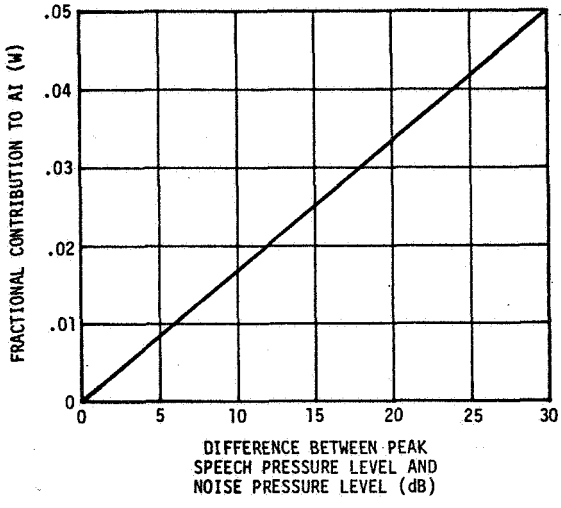


Figure 3-13. Contribution to the Articulation Index

6) For octave bands of ---	Multiply W by ---
150-300 Hz	1
300-600 Hz	1
600-1200 Hz	5
1200-2400 Hz	7
2400-4800 Hz	5
4800-9600 Hz	1

7) Add the values obtained in step 6 to obtain the applicable articulation index.

Table 3-22. Intelligibility Criteria

An AI of	Provides communications . . . .
0.7 to 1.0	Satisfactory to excellent
0.3 to 0.7	Slightly difficult to satisfactory; up to 98 percent of sentences are heard correctly
0.0 to 0.3	Impossible to difficult; special vocabularies and radio-telephone voice procedures are required.

3.2.3.4.5 Noise Criteria (NC) - A more sophisticated, general standard for determining the effect of noise on communication is based on noise criteria (NC). These criteria were developed to evaluate noise in offices and workspaces, and are essentially an extension of the SIL's from a single number to a set of numbers representing the octave-band spectra. The NC are designed to take into account both the effect of noise on speech communication and the annoyance of the noise, since the former has an important influence on the latter. Figure 3-14 contains the NC curves and Table 3-23, the NC for various situations. Note that the rank of the criteria (for example, 40 in NC-40) is the octave-band level in the 1200-to-2400 Hz band, and that a noise with a spectrum the same as the NC curve would have an SIL equal to the rank. As with the SIL's, these criteria should be used only when the noise is fairly steady and has a continuous spectrum. To find the NC of a given communication environment, proceed as follows:

1) Measure or predict the noise in octave bands.
2) Plot the octave-band spectrum of the noise.
3) Find the NC curve which is higher than any of the measured or predicted octave-band level in each octave band; this is the NC of the noise environment.
4) Find the description of the communication environment in Table 3-23.

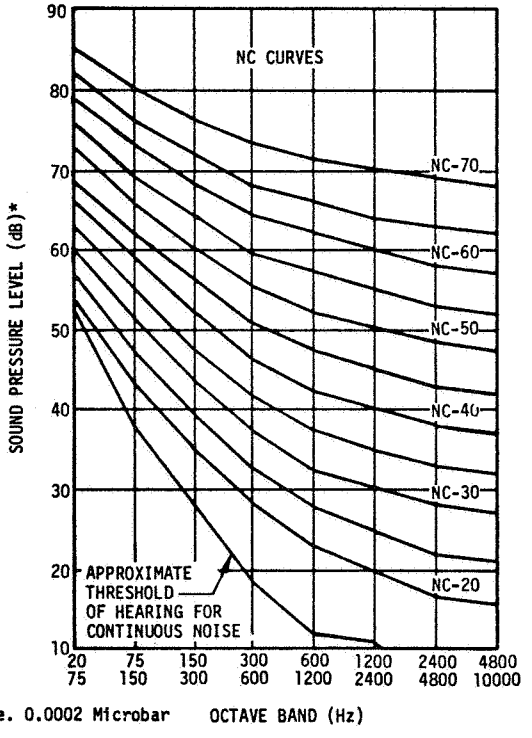


Figure 3-14. Noise Criteria Curves

Table 3-23. Recommended Noise Criteria for Offices and Workspaces

Offices	
NC (or NCA) Curve	Communication Environment
NC-20 to NC-30	Very quiet office; suitable for large conferences. Telephone use satisfactory.
NC-30 to NC-35	"Quiet" office; satisfactory for conferences at a 15 ft table; normal voice, 10 to 30 ft. Telephone use satisfactory.
NC-35 to NC-40	Satisfactory for conferences at a 6 to 8 ft table; normal voice, 6 to 12 ft. Telephone use satisfactory.
NC-40 to NC-50	Satisfactory for conferences at a 4 to 5 ft table; normal voice, 3 to 6 ft; raised voice 6 to 12 ft. Telephone use occasionally slightly difficult.
NC-50 to NC-55	Unsatisfactory for conferences of more than two or three people; normal voice, 1 to 2 ft; raised voice 3 to 6 ft. Telephone use slightly difficult.
Above NC-55	"Very noisy." Office environment unsatisfactory. Telephone use difficult.
Workspaces, Shop Areas, Etc.	
NC-60 to NC-70	Person-to-person communication with raised voice satisfactory, 1 to 2 ft; slightly difficult, 3 to 6 ft. Telephone use difficult.
NC-70 to NC-80	Person-to-person communication slightly difficult with raised voice, 1 to 2 ft; slightly difficult with raised voice, 1 to 2 ft; slightly difficult with shouting, 3 to 6 ft. Telephone use very difficult.
Above NC-80	Person-to-person communication extremely difficult. Telephone use unsatisfactory.

Note: Noise measurements made for the purpose of comparing the noise in an office with these criteria should be performed with the office in normal operation, but with no one talking at the particular desk or conference table where speech communication is desired, i.e., where the measurement is being made. Background noise with the office unoccupied should be lower, say by 5 to 10 dB.

Figure 3-15 presents the alternate noise criteria (NCA), which are the maximum octave-band levels recommended when the noise is steady and free from beats between low-level components.

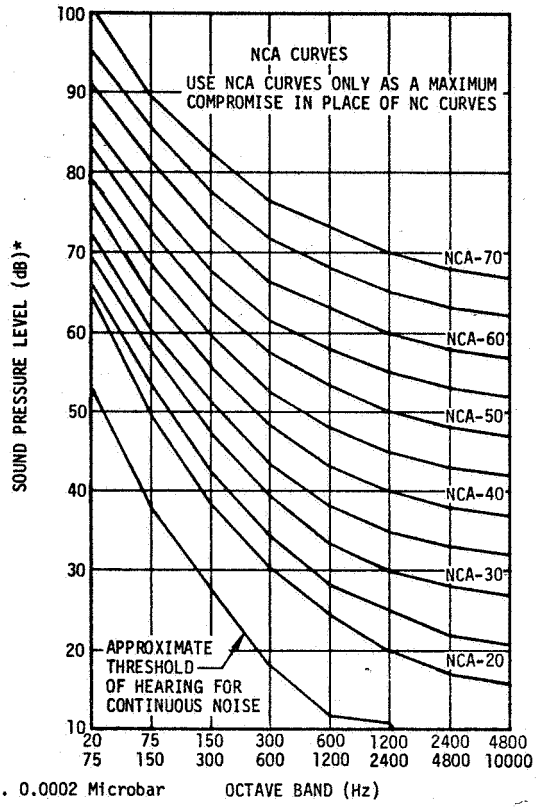


Figure 3-15. Alternate Noise Criteria

3.2.3.4.6 Hearing Damage Risk Criteria - Figures 3-16, 3-17, and 3-18 are damage risk contours for one exposure per day to certain one-third octave, full octave and pure tones of noise as accepted by the CHABA Working Group NG. 46 (Reference 1.). If any single band exceeds the damage risk contours specified, the noise can be considered as potentially unsafe. The relations shown in the figures are based either upon direct measures of temporary threshold shift (TTS) or permanent noise induced hearing losses resulting from exposure to sound. These data have been verified from sufficient research by more than one independent investigation with the following exceptions:

a) The maximum levels specified for the top curves in the figures are estimates not supported by direct experimental data.

b) The data supporting the damage risk contours for pure tones are not as extensive as those for octave or one-third octave bands of noise.

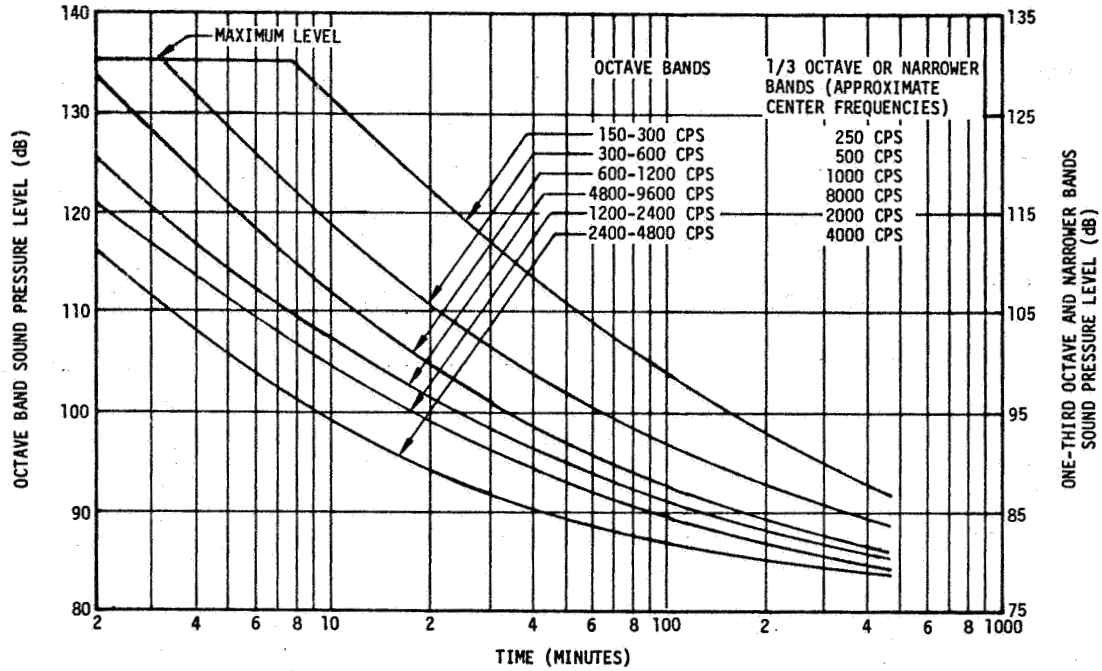


Figure 3-16. Damage Risk Contours for One Exposure Per Day to Certain Octave and One-Third Octave or Narrower Bands of Noise

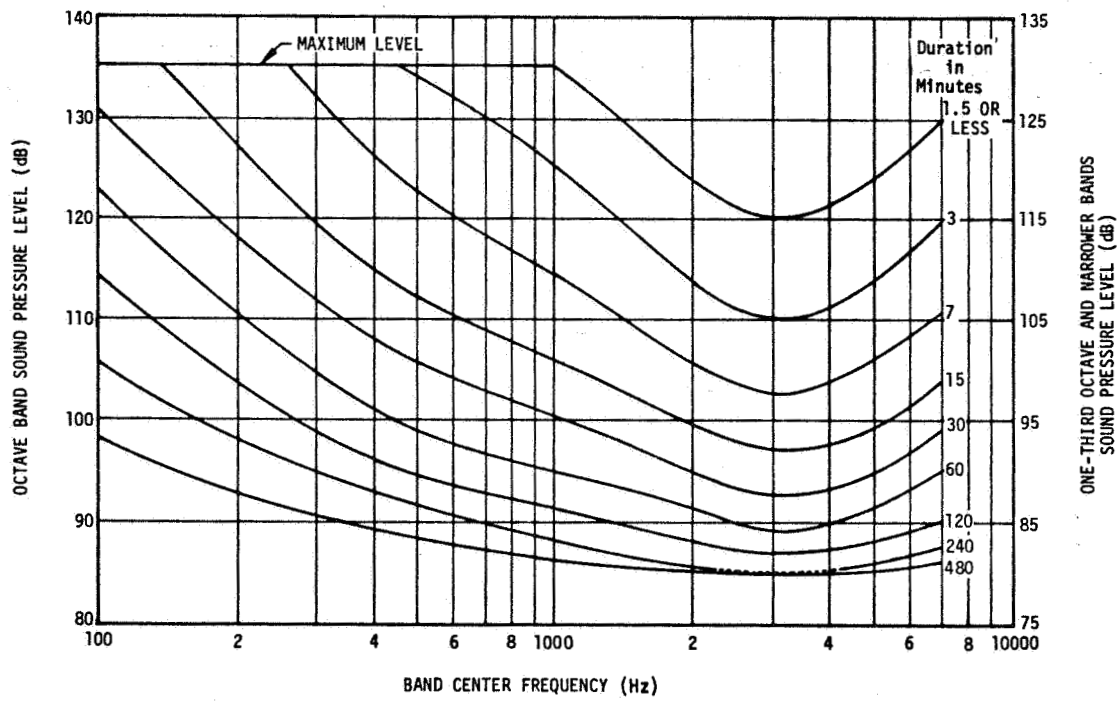


Figure 3-17. Damage Risk Contours for One Exposure Per Day to Octave and One-Third Octave or Narrower Bands of Noise

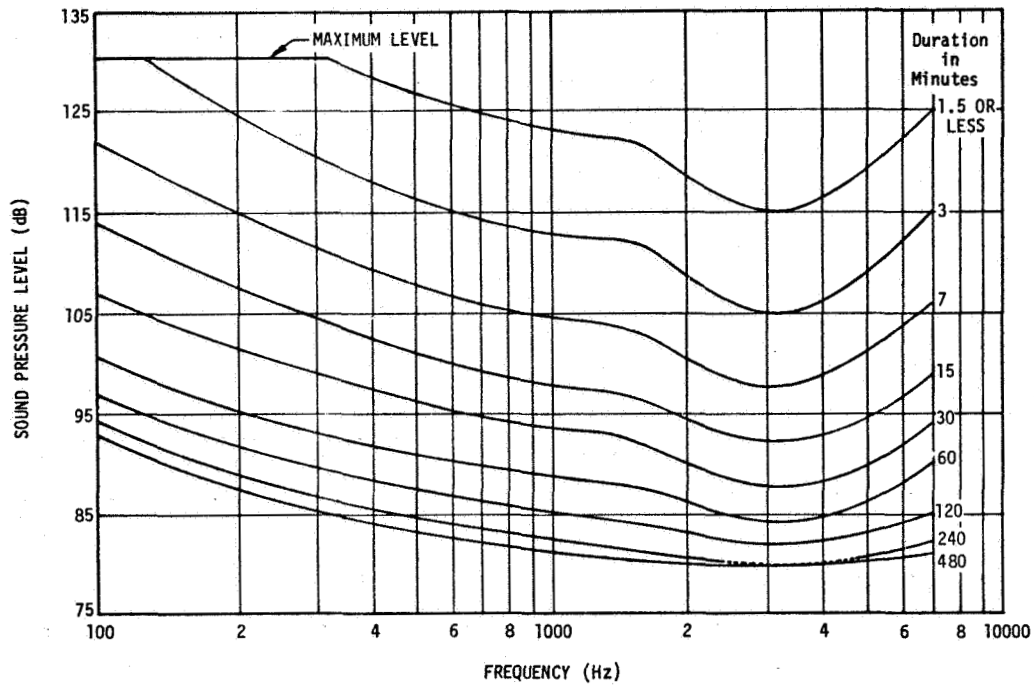


Figure 3-18. Damage Risk Contours for One Exposure Per Day to Pure Tones

3.2.4 Noise Effects.

3.2.4.1 Performance. Work efficiency on tasks involving alertness over extended time periods has been observed to be reduced in noise environments of the order of 100 dB. In fact, levels of noise exceeding 90 dB degrade performance of multiple-choice, serial reaction type tasks. In addition, it has been noted that high-pitched noise having a major spectral content above 2000 Hz has a more deleterious effect than low-pitched noise below 2000 Hz. It has also been concluded that in tasks calling for both speed and skill, that noise increases the incidence of mistakes although the rate of working may remain unchanged.

In general, it may be said that the effect of intense noise on work is distracting rather than disabling, and noise is most troublesome when it is irrelevant to the task at hand. Extremely high noise levels can interfere with the accuracy of precision manual - dexterity tasks through noise-induced vibrations of body parts. They can affect the sense of equilibrium, add to disorientation, motion sickness, etc., depending on the specifics of the environment and the type of noise. It should be remembered that the

level of noise required to exert a measurably degrading effect on task-performance (overall SPL greater than 90 dB) is considerably higher than the highest level which are acceptable according to other criteria (e.g., hearing conversation of communication). See Table 3-24 for the noise effects on performance.

Table 3-24. Performance Effects

SPL dB	Effect
> 90	Degrades multi-choice performance
100	Reduces alertness
114	Speed and skill mistakes increase

3.2.4.2 Non-Aural (low frequency) Effects. Exposure to low-frequency, high-intensity noise has had little study prior to the space program. Pain thresholds had been recorded at approximately 179 dB for static pressure, 165 dB at 3 Hz, and decreasing to the range of 140 dB from 15 to well above 100 Hz. The noise-experienced subjects of previous studies had observed no sensations of disturbed equilibrium or nausea during exposures to tones below 30 Hz even at SPL's inducing pain.

However, recent studies performed by Mohr, et al., have indicated new information relating to effects on humans of low-frequency and infra-audible sound.

In summary, the maximum infrasonic exposure levels produced by the available simulation devices did not reach the voluntary tolerance limit for noise-experienced subjects; however, the unusual sensations excited by the oscillating pressure environment could be alarming to the naive observer. In the very low sonic frequency range, chest wall vibration, gag sensations, and respiratory rhythm changes were regularly observed. But the limits of voluntary tolerance were not exceeded by the exposure levels available from the various devices.

In the 50-100 Hz range, the simulator capability for discrete-frequency noise was sufficient to generate subjectively intolerable environments.

Responses including headaches, choking, coughing, visual blurring, and fatigue were sufficiently alarming to preclude undergoing higher level exposures without more precise control of the noise environment and definition of the physiological effects elicited.

The presently available data thus support the conclusion that noise-experienced human subjects, wearing ear protectors, can safely tolerate broad-band and discrete frequency noise in the 1-100 Hz range for short durations at sound pressure levels as high as 150 dB. At least for the frequency range above 40 Hz, however, such exposures are undoubtedly approaching the limiting range of subjective voluntary tolerance and of reliable performance. As would be expected, the responses reported by these five subjects during the various test series reflect considerable variability in the subjective effects. At present, the magnitude of possible individual and group variability cannot be accurately estimated. See Table 3-25 for values of non-aural effects.

Table 3-25. Non-Aural Effects

SPL dB	Frequency (Hz)	Effect
> 150	77	Anal sphincter resonates
> 150	40-60	Chest resonates
> 150	700-1500	Blurred vision
120-150	1.6-4.4	Vertigo, disorientation, nausea, and vomiting
120 continuous	< 7500	Irritability and sense of fatigue

3.2.4.3 Discomfort Effects. Apart from subjective effects and interference with performance and communication, intense noise can also induce certain neurophysiological reactions. For example, very loud or sudden noises can evoke fear and avoidance reactions in humans and animals. Continuous loud jet noise can produce irritability and a sense of fatigue.

Recent investigators have attempted to investigate the hypothesis that greater human energy expenditure is needed for adaptation to loud

unpredictable noise, in contrast to loud predictable noise, and that this increased energy expenditure is reflected in a lower tolerance for frustration and in greater deterioration of performance on tasks. The actual discomfort and damage noise range to the ear is shown in Tables 3-26 and 3-27.

Table 3-26. Noise Discomfort Range

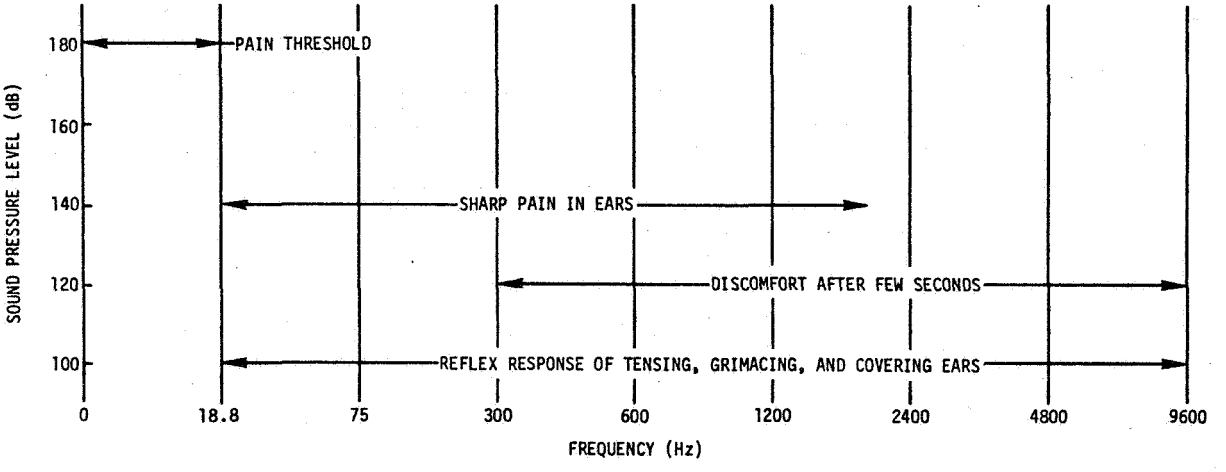


Table 3-27. Hearing Damage

Condition	SPL dB
Single blast pulses of low frequency	> 175
Sound cycles in range of maximum ear sensitivity	> 155

3.2.5 Noise Control Applications. Noise control for extraterrestrial architectural design will include the reduction of undesirable sound, and the introduction of desirable sound for masking effects and the alleviation of mental stress which can result from the absence of sound.

The noise criteria for the various areas and performance requirements for the occupants must be established. Acoustical design and analyses should then indicate whether:

- The sound level of the auditory signal devices is sufficiently above the ambient noise levels to permit reception of the signal. Particular attention should be given to auditory signals indicating malfunction. Auditory warning signals must be easily detectable and must be quickly and accurately identifiable. They should not be of an intensity of frequency content to induce discomfort of panic response.
- The auditory devices are sufficiently distinctive to permit discrimination between them under all ambient noise conditions.
- The ambient noise level is sufficiently low in either the shirtsleeve or pressure suit environments, to permit face-to-face verbal communications when required with an acceptable level of intelligibility, with half effort.
- The signal-to-noise ratio and bandwidth for the intercommunication equipment is sufficiently high to permit an acceptable level of intelligibility.
- The ambient noise level does not exceed intensity levels and durations which cause undue discomfort or could be expected to cause temporary or permanent damage.

Based on these comparisons, if there are any areas disclosed in which performance and/or tolerance limits are exceeded or marginal, analyses should be performed to determine where corrections can be made. These include:

- Reduction of the ambient noise level at its source.
- Reduction of the ambient noise level in the cabins through the use of sound absorbing materials.
- Reduction of the ambient noise level in the cabins through the use of sound absorbing materials.
- Reduction of the ambient noise level at the ear through the use or modifications of helmet, earphones, and/or earplugs.
- Modification of the auditory signal devices to increase the signal-to-noise ratio and/or distinctiveness.
- Modification of the intercommunication equipment to increase the intelligibility.
- Modification in the mode of operation to be less dependent on auditory signal devices and/or verbal communications, with the appropriate programming of face-to-face and interphone modes.

Usually, the preferred approach to reducing equipment noise is to treat the source through the use of isolators, enclosures, etc. When this approach is impractical, treatment of the receiving space can be accomplished

by application of sound absorbing materials. Transmission of noise from one area to another can be controlled by treatment and isolation of partitions, ceilings, floors, and common ducts connecting the areas. Major emphasis is placed on eliminating direct air paths from one area to another.

Studies will be required to insure that materials used in sound treatments meet requirements for flammability, toxicity, cleanliness, etc. Absorption materials which are optimum for standard atmospheric pressure may not be applicable at reduced pressure. In the application of noise control techniques, the analyses must account for the effects of reduced atmospheric pressure on noise sources, loudspeakers, speech and hearing (if applicable). See Table 3-28 for absorption coefficients of various materials.

Table 3-28. Sound-Absorption Coefficients

Material	Absorption Coefficient Frequencies (Hz)						Noise-Reduction Coefficient	Weight (lb/ft^2)	Surface
	128	256	512	1024	2048	4096			
Metal (steel and aluminum)	0	0	0	0	0	0	0	Depends on thickness	Any
Cushion-tone Cork, 3/4"	.10	.28	.66	.91	.82	.69	.65	1.05	484 holes/ft^2, 3/16" dia., 5/8" deep, painted
Fiberglass Tile, 3/4"	.04	.20	.63	.91	.82	.82	.65	0.69	Painted
Wood Floor	.05	-	.03	-	.03	-	.03	-	-
Cork or Rubber Tile	-	-	.03-.08	-	-	-	.05	-	-
Glass	.035	-	.027	-	.02	-	.02	-	-

3.2.6 Sample Calculations

3.2.6.1 Example of Spacecraft Interior Acoustic Calculations. An orbital spacecraft has the following applicable internal dimensions: total surface areas - 1490 square feet, volume = 1600 cubic feet. The composite average absorption coefficient applicable to the internal spacecraft surfaces is 0.08. A sound source with a power of 0.01 acoustic watts is put in the enclosure. There are 5 people in the spacecraft with an absorbing surface of 100 square feet and an average absorption coefficient of 1.0. Determine: (a) the reverberation time (T) of the interior of the spacecraft, and (b) the interior sound pressure level (SPL) at 5 feet for a directivity index of 1.

Given: S_1 = Absorbing surface-spacecraft interior = 1490 ft^2

S_2 = Absorbing surface-5 crewmen = 100 ft^2

S_v = Total absorbing surface = $S_1 + S_2$ = 1690 ft^2

α_1 = Absorption coefficient of spacecraft interior = 0.08

α_2 = Absorption coefficient of crewmen = 1.0

$\bar{\alpha}$ = Average absorption coefficient = $\frac{S_1\alpha_1 + S_2\alpha_2}{S_1 + S_2}$ = 0.138

V = Volume of spacecraft = 1600 ft^3

W = Power emitted by the sound source = 0.01 watts

r = Distance from the center of the sound source = 5.0 ft.

Q = Directivity index = 1.0

PWL = Sound power level = $10 \log \frac{W}{10^{-13}} = 10 \log \frac{.01}{10^{-13}}$ = 110 dB

R = Room constant = $\frac{S_v\bar{\alpha}}{1-\bar{\alpha}} = \frac{(1690)(0.138)}{1-0.138}$ = 270.6 ft^2

Solution: $T = \frac{0.049V}{S_v\bar{\alpha}} = \frac{(0.049)(1600)}{(1690)(0.138)} = 0.336$ seconds

$$SPL = PWL + 10 \log \left(\frac{Q}{4\pi r^2} + \frac{4}{R} \right) + 0.5$$

$$= 110 + 10 \log \left(\frac{1}{(4\pi)(25)} + \frac{4}{1250} \right) + 0.5$$

$$= 110 + 10 (-2.2) + 0.5 = 88.5 \text{ dB re. } 0.0002 \text{ microbar}$$

3.3 TEMPERATURE

3.3.1 Requirements. Thermal control and limits within any confined space are required for mission success. Not only is thermal control essential for crew comfort, but equipment operation is dependent on the surrounding environment. However, the crew thermal limits are the determining factor since equipment thermal limits exceed the human limits. Crew comfort and performance are to a large extent determined by the environment thermal limits of the space occupied by the crew. To determine these limits, the physical parameters and the more subjective element of the sensation the crew will feel are considered. The two sensations that are used to reflect the comfort zone are warm and cool since these two feelings are the most common terminology associated with a comfortable temperature. Any environmental condition outside the comfort zone is either uncomfortably warm or uncomfortably cool.

The principal factors affecting human comfort in a gaseous environment include the dry-bulb temperature, relative humidity, gas flow rate, total pressure, and density of the gas. Some other related factors that must be considered are crew activity which determines metabolic rate, temperature of the enclosure structure, type of clothing, crew physical condition, and gravity condition. Combining the principal factors into a single value will determine the effective temperature. The effective temperature can be defined as an empirical index of the thermal effect of the environment upon the human body. This index is acceptable for use when radiant heat exchange is relatively insignificant in comparison with other modes. Spacecraft, with adequate insulation, will normally be in this category.

Equipment heat loads such as lights have not been accounted for since they are unknown at this time. This is a significant part of the total heat load and cannot be overlooked when determining environmental control equipment.

3.3.2 Definitions.

Comfort Zone - The area enclosed by the boundaries of the effective temperatures and relative humidity that induces a feeling of comfort to humans. All factors affecting the thermal condition of man are used in determining the comfort zone.

Dry-Bulb Temperature - The terms temperature, air temperature, ambient air temperature, and dry-bulb temperature are all synonymous. They can be measured with a common thermometer.

Wet-Bulb Temperature - This is the temperature obtained when the thermometer bulb is cooled by the rapid evaporation of water by air moving at a velocity of 900 feet per minute. Wet-bulb temperature varies with humidity and is the same as dry-bulb temperature when the humidity is 100 percent.

Relative Humidity - This is the ratio between absolute humidity and the saturation value at a given temperature expressed in percent. When a quantity of air holds all the water vapor it can, it is said to be saturated and the humidity is 100 percent.

Gas Flow Rate - This is the velocity at which the gas moves past an object and is expressed in feet per minute. Determining factors are the mass of gas, volume, and rate of gas change per unit of time.

Clo Factor - The thermal resistance of clothing to the flow of heat from or to the body is expressed in Clo units. The Clo is a unit of insulation and is the amount of insulation necessary to maintain comfort and a mean skin temperature of 92°F in a room at 70°F with air movement not over 10 feet per minute, humidity not over 50 percent, with a metabolism of 50 calories per square meter per hour. On the assumption that 76 percent of the heat is lost through the clothing, a Clo may be defined in physical terms as the amount of insulation that will allow passage of 1 calorie per square meter per hour with a temperature gradient of 0.18°C between the two surfaces.

$$1\ \text{Clo} = \frac{0.18°\text{C}}{\text{cal/m}^2\text{/hr}}$$

Metabolic Rate - Metabolic rate is the thermal exchange between the human body and the environment. The rate of heat production, metabolism, is always positive in value and is expressed in Btu/hr.

Pressure - This refers to the absolute total pressure of the environment and is expressed in pounds per square inch. The pressures considered for this study are 5, 10, and 14.7 psia with a constant partial pressure of oxygen at 3.01 to 3.45 psia.

Radiation - This is a process by which heat flows from a high-temperature body to a body at a lower temperature when the bodies are physically separated with no barrier between them. Heat transfer by radiation becomes increasingly important as the temperature of an object increases. The intensity of the emissions depends on the temperature and nature of the surface.

Conduction - Conduction is a process by which heat flows from a region of higher temperature to a region of lower temperature within a medium (solid, liquid, or gaseous) or between different mediums in direct physical contact. In conduction heat flow, the energy is transmitted by direct molecular communication without appreciable displacement of the molecules.

Convection - Convection is a process of energy transported by the combined action of heat conduction, energy storage, and mixing

motion. The transfer of energy by convection from a surface whose temperature is above that of a surrounding fluid takes place in several steps. First, heat will flow by conduction from the surface to adjacent particles of fluid. The fluid particles will then move to a region of lower temperature in the fluid, due to the increase in temperature and internal energy of the fluid particles, where they will mix with, and transfer a part of their energy to, other particles. This is known as free convection as the change in density is the motivating force causing the mixing motion. When the mixing motion is induced by some external agency, such as a pump or blower, the process is called forced convection. An increase in humidity increases heat transfer to the body for a given temperature difference and air velocity, since water vapor has a heat absorptive capacity twice that of dry air.

Evaporation - The evaporative heat exchange mode is limited to sensible and insensible perspiration from the surface of the body. The evaporative heat loss is a function of volume flow rate, absolute humidity, temperature, and pressure of the atmosphere. If the air is saturated with water vapor at skin temperature, evaporation does not occur; in fact, if the vapor content is such that the air will be super-saturated when cooled to skin temperature, condensation will occur with rapid transfer of heat to the skin. If the human body is surrounded by saturated air at a higher temperature, it responds by producing an excess amount of perspiration, without losing any heat. A continuation of this condition may result in fever, discomfort, weakness, rapid heart action, difficulty in breathing, delirium, and collapse.

3.3.3 Engineering Data.

3.3.3.1 Thermal Equilibrium. To determine the temperature criteria for spacecraft applicability, the avenues must be known by which heat is exchanged between man and the environment. These avenues, radiation, convection, conduction, and vaporization, represent the means that must be considered to keep the human body in equilibrium, and therefore comfortable. Exchanges of radiation may occur with surfaces having higher or lower temperatures than that of the skin or radiation may be absorbed by the skin from high temperature sources such as the sun. The body may exchange heat by convection; and this is an important mode of heat loss, especially if the velocity of the air around the body is high and of a low temperature. Body heat exchanged by conduction occurs when direct physical contact is made with objects. Heat is lost by vaporization from the lungs through respiration and the skin by sweating. Body heat may also be lost in urine and feces. The body also stores heat in the tissues and body fluids which is used to maintain the body thermal balance.

The conditions for thermal equilibrium between the human body and the environment can be examined in terms of the biothermal equation. This equation attempts to balance the normal heat gains and losses and is usually expressed as follows:

$$q_{sr} + q_m = \pm q_s \pm q_r \pm q_c \pm q_v \pm q_k - q_e \pm q_w$$

Table 3-29 gives the functions or criteria affecting these terms and their effect upon the biothermal equation.

For a state of thermal equilibrium, the heat storage rate is zero ($q_s = 0$). The conductive heat transfer mode is usually quite small and can be assumed, in most instances, to be included in the radiant and/or convective heat transfer terms ($q_k = 0$). Finally, if external heat fluxes are accounted for in terms of induced environmental parameters, such as internal air and wall temperatures, the term (q_{sr}) can be omitted from the expression.

Table 3-29. Components of the Biothermal Equation

Term	Function	Effect on System
Metabolism, q_m	f(activity level, body temp.)	Gain at all times
Solar radiation, q_{sr}	f(h_{sr}, t)	Gain when present
Infrared radiation, q_r	f(h_r, t)	Gain: $t_w > t_g$; Loss: $t_w < t_g$
Convection, q_c	f(h_c, t)	Gain: $t_a > t_g$; Loss: $t_a < t_g$
Evaporation, q_e	f(D_v, ΔC, P, t)	Loss in all usual conditions
Respiration, q_v	f(Resp. mass flow, P, t)	Small gain or loss
Storage, q_s	f(W, C_p, A_b, $dt_b/d\theta$)	Gain: $dt_b/d\theta > 0$; Loss: $dt_b/d\theta < 0$
Work, q_w	nature of activity	Gain: Work done on body; Loss: Work done by body

With comfort as the reference state ($q_s = 0$), the biothermal equation can be expressed as:

$$q_m = \pm q_r \pm q_c + q_e + q_v + q_w$$

and the system can be examined qualitatively in the light of these terms after they have been adequately defined.

- Heat of metabolism (q_m) is considered to be the sum of the basal metabolism rate (energy required to maintain the body in good health and at equilibrium temperature while at rest) plus an incremental increase in heat energy due to activity and/or stress.
- Radiant heat exchange (q_r) is a measure of the heat lost (or gained) as a result of the temperature difference between the skin of the human body and the walls of the surroundings.
- Convective heat exchange (q_c) is a measure of the heat lost (or gained) as a result of the temperature difference between the skin and the immediate atmosphere.
- Evaporative heat exchange (q_e) is the heat exchange resulting from the vaporization of moisture at the surface of the skin.
- Respiratory heat exchange (q_v) is a measure of the heat lost (including vaporization of water) from the lungs due to respiration.

In any environment, all of the above modes of heat transfer may be present. In general, the ambient dry bulb temperature, humidity, air velocity, and ambient pressure determine the partition of mechanisms actually used by the body.

3.3.3.2 Design Criteria. The biothermal equation delineates the parameters that must be considered to arrive at a comfort level for man. It is important to note that man has the ability to live and function within a broad range of thermal conditions because of his capacity to maintain a relative constant deep body temperature. This deep body temperature is also referred to as the body core temperature and is considered normally to be 98.6°F. Skin temperature can vary for different parts of the body with the mean being approximately 93°F. With these considerations in mind, the following table was prepared to be used as a guide in determining the environmental limits of a spacecraft.

Table 3-30. Environmental Design Criteria

Item	Limits	Remarks
Temperature, Air		
Minimum	60°F at 0.0 Clo 45°F at 1.0 Clo	Experimental data show low air temperatures are offset by high metabolic rates or radiation. Prevents uncomfortable cooling of any skin area.
Maximum	100°F	To avoid high skin temperature and prevent uncomfortable heating of any skin area
Temperature, Surface		
Minimum	55°F	To prevent overcooling or overheating of skin areas coming in contact with the surfaces
Maximum	105°F	
Gas Flow Rate		
Minimum	15 ft/min	Equal to natural convection. This is required to avoid dead hot or cold gas pockets, dissipation of carbon dioxide and other waste gases, and avoids large changes in convective heat loss with body movement.
Maximum	100 ft/min	Flow rates above this level are subjectively drafty and cause uncomfortable local skin temperatures.
Humidity		
Minimum	8 mm Hg partial	Below this level, the mucus membranes begin to dry resulting in discomfort and increased possibility of respiratory infection.
Maximum	95 percent R.H.	At this relative humidity level, liquid water is usually condensed on some surfaces. At high metabolic rates where sweating may occur, humidity will be limited by comfortable air or wall temperature.

Table 3-30 on environmental design criteria did not incorporate the element of time in the limits of the environmental factors or the tolerance levels. For this data, Figure 3-19 is presented to show the thermal requirements for tolerance and comfort in crew compartments.

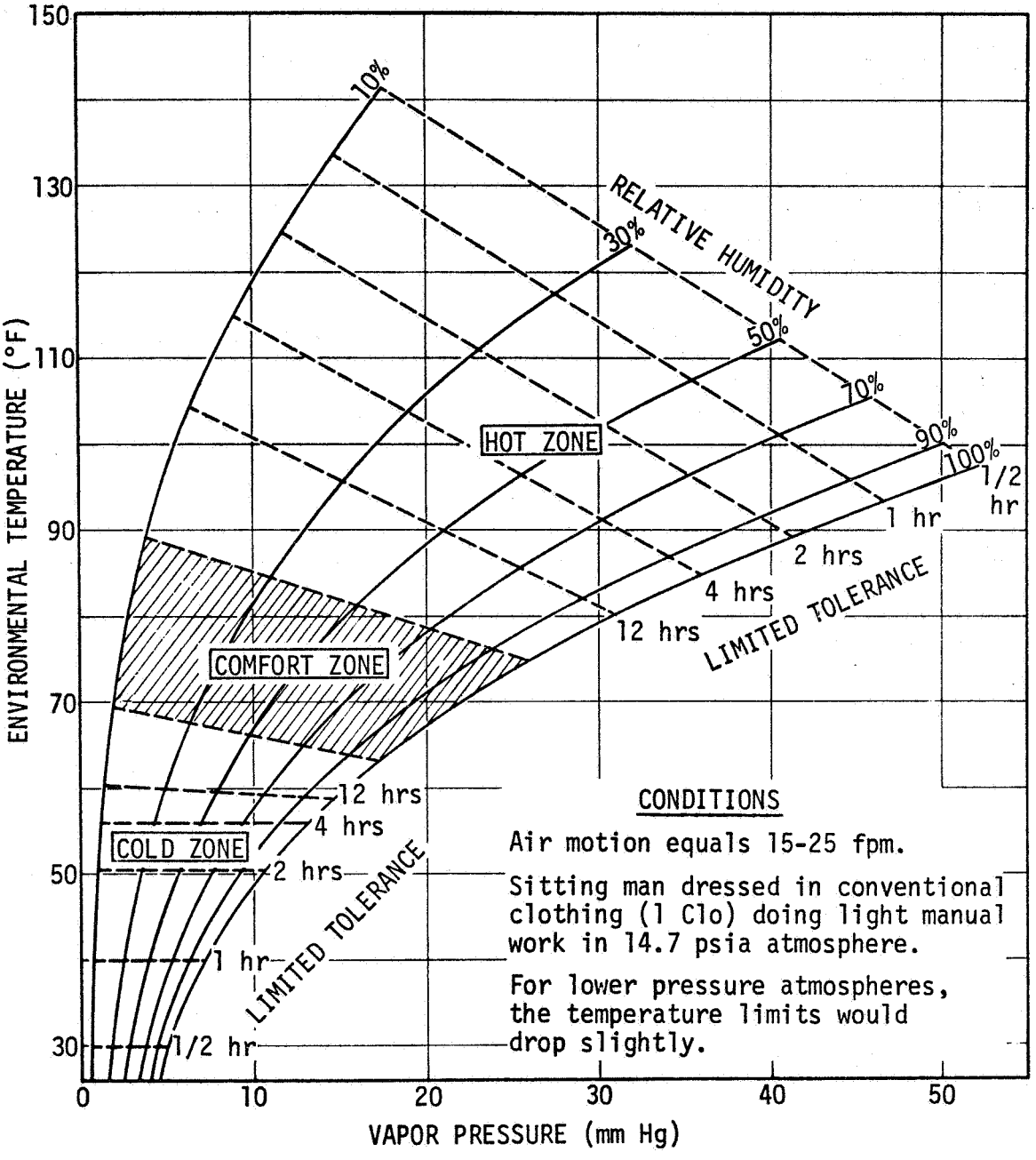


Figure 3-19. Thermal Requirements for Tolerance and Comfort in Crew Compartments

The insulation effect of clothing with regard to time must be considered for various temperatures. Figures 3-20 and 3-21 are presented to depict the approximate human time tolerance relationship with temperature and the clothing requirements for men working at different temperatures.

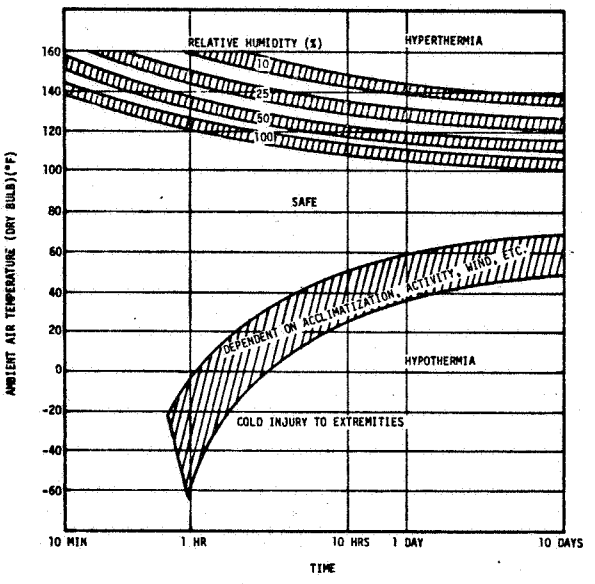


Figure 3-20. Approximate Human Time-Tolerance Temperature with Optimum Clothing

Temperature		Clothing Requirements (Clo)	
°C	°F		
26.7	80	0.0-	Nude
21.1	70	0.5-	Light
10.0	50	1.2	Medium
- 1.1	30	2.0	
-12.2	10	2.8	
-23.3	-10	3.8	Heavy
-34.4	-30	4.8	
-45.6	-50	5.5	

Conditions:

- at rest, standing
- 50% humidity
- 15 fpm air flow

Figure 3-21. Clothing Requirements for Various Temperatures

3.3.3.3 Atmospheric Composition Comparison. In addition to a nitrogen-oxygen (N_2-O_2) atmosphere, the possibility of using a helium-oxygen (He-O_2) atmosphere exists. Generally, the comfort zones for the helium-oxygen environment are higher than for a nitrogen-oxygen atmosphere. This effect is negligible at low Clo values but becomes more significant (7°-10°F) at Clo values near 1.0. In all cases, the clothing values were corrected for increased thermal conductivity of the helium mixtures.

For normal gas velocities of 20 feet/minute to 80 feet/minute, medium clothing (0.7 Clo) and one earth gravity, the data in Table 3-31 are representative for the temperature comfort zone.

Table 3-31. One-g Crew Comfort Temperature Ranges for He-O_2 and N_2-O_2 Atmospheres

Atmosphere	5 psia (3.5 psia O_2)	7 psia (3.5 psia O_2)
He-O_2	92°F upper limit 82°F average 73°F lower limit	94°F upper limit 85°F average 76°F lower limit
N_2-O_2	83°F upper limit 77°F average 71°F lower limit	84°F upper limit 78 F average 73°F lower limit

From these data, it can be seen that with a helium-oxygen atmosphere, a 5° to 7°F higher temperature can be used and crew comfort will still be maintained.

An assumption made for the comparison was that the temperature of the spacecraft interior wall is very close to the spacecraft cabin gas temperature. For several reasons, this assumption is reasonable until vehicle design details are known. High-performance insulation will minimize heat lost or gained by the spacecraft. In addition, equipment items in the cabin tend to block radiation. Insulation in the spacecraft and on the equipment will prevent moisture condensation on the walls and also prevent large fluctuations in wall temperature. Therefore, mean radiation will be almost equal to cabin gas temperature. If the radiated temperatures

are greater than the cabin temperature, equations show that the comfort temperature difference between a $He-O_2$ and a N_2-O_2 atmosphere are greater than shown above.

The following are representative data modified to approximate zero-gravity conditions. The gas velocity is 50 feet/minute and the metabolic rate is 460 Btu/hour. Wall temperature is assumed to be within $\pm$ 1°F of average cabin temperature. These data are presented in Table 3-32.

Table 3-32. Zero-g Crew Comfort Temperature Ranges for $He-O_2$ and N_2-O_2 Atmospheres

Clo Factor	5 Psia	7 Psia	10 Psia
$He-O_2$			
0 Clo	76° - 80°F	78° - 81°F	79° - 83°F
0.5 Clo	72° - 75°F	75° - 78°F	77° - 80°F
1.0 Clo	68° - 71°F	72° - 75°F	74° - 78°F
N_2-O_2			
0 Clo	75° - 79°F	76° - 80°F	77° - 81°F
0.5 Clo	68° - 71°F	69° - 72°F	70° - 73°F
1.0 Clo	61° - 64°F	61° - 65°F	62° - 66°F

Although no data were presented at 14.7 psia, it can be seen from the above data that at this higher pressure the temperature comfort zone will be slightly elevated for both mixtures and the difference between the two mixtures will remain substantially the same or increase slightly.

Two effects seem to be present to account for the higher temperature comfort zone with the helium-oxygen atmosphere. One is due to the larger gas conductivity of helium. The second results from the influence of gas conductivity on the resistance to heat flow in the clothing. Thermal resistance of clothing appears to be dependent on the thermal resistance of the atmospheric gas entrapped in the clothing.

More extensive testing is required to further evaluate the effects of a helium-oxygen atmosphere. For example, the effects of the mixture during a heavy exercise period with its increased metabolic rate need to be investigated. Tests at varying pressures with different amounts of clothing should be conducted. The long-term physiological effects of a helium-oxygen atmosphere are largely unknown. Leakage rates for $He-O_2$ are higher than for N_2-O_2 environments.

These factors lead to the conclusion that a nitrogen-oxygen atmosphere is most suitable for the anticipated mission profiles. Special applications of the helium-oxygen atmosphere might be possible in some specific cases.

3.3.4 Crew Effects.

3.3.4.1 Humidity Control. For any mission, the controllable factors that will affect the crew from a physical and mental standpoint are the dry-bulb temperature, relative humidity, and gas velocity. If the limits of any one of these are exceeded, the other two factors will be affected. It is almost a direct relationship in that as discomfort increases, performance efficiency decreases. Of the controllable factors, relative humidity is difficult to detect when it is out of the acceptable range before some physical effects are recognized. The most physical harm is done when the relative humidity is too low, below approximately 10 percent relative humidity or 8 mm Hg vapor pressure, for this will dry out and irritate the mucous membranes. However, it must be noted that relative humidity can vary more than any other factor without affecting crew performance.

3.3.4.2 Heat Regulation. The human body modifies its surface with variations in the environment so as to maintain heat balance in the body. This is accomplished by varying the size of the blood vessels to either restrict or increase blood flow through the skin, activating sweat glands, and adding or removing clothing. Figure 3-22 depicts the human body temperatures and zones of temperature regulations.

3.3.5 Application. In determining the temperature criteria for spacecraft applicability, the activities and their corresponding metabolic rates for each area of the spacecraft are required. It is also necessary to know to what extent each factor, that determines the comfort zone, contributes to the total environment. To satisfy the first requirement, Tables 3-33

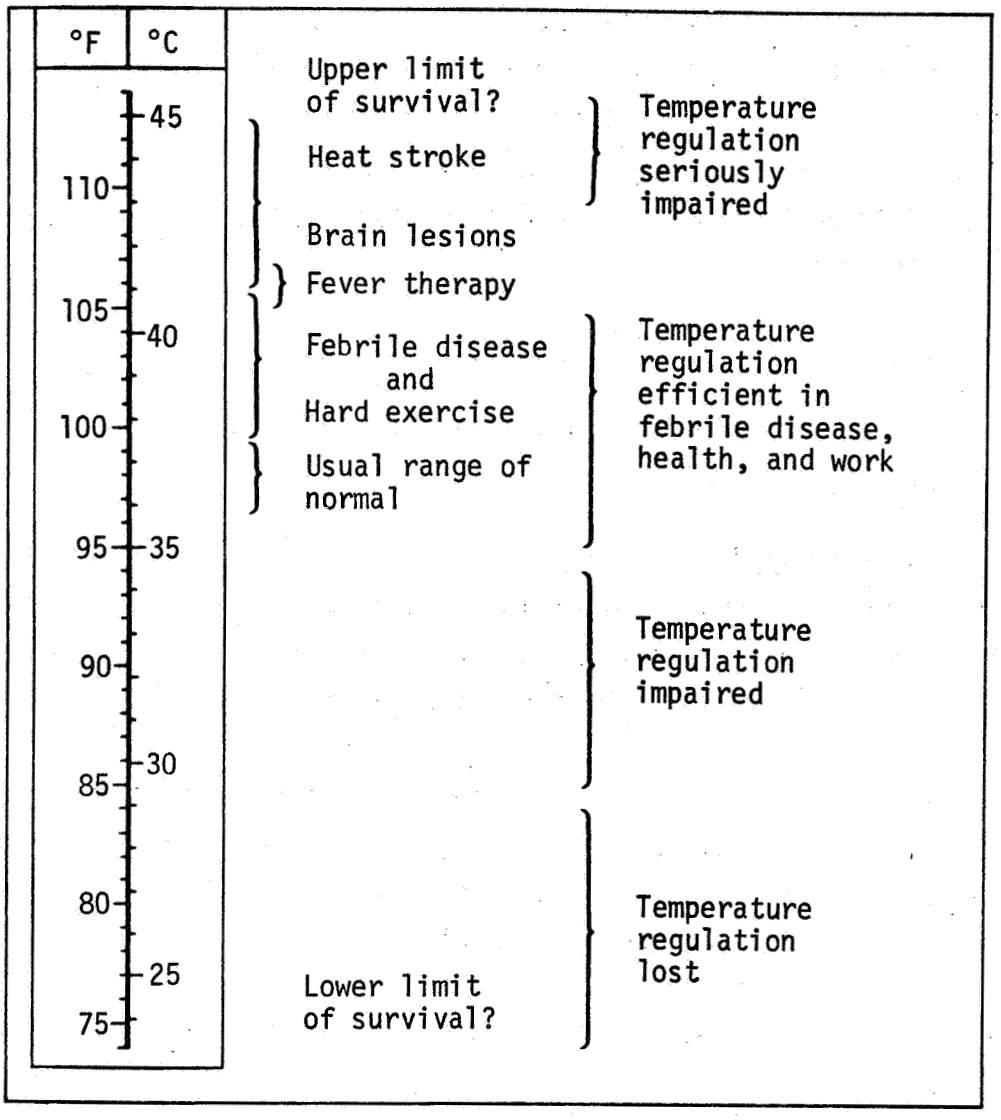


Figure 3-22. Human Body Temperature Extremes Defining Zones of Temperature Regulations

and 3-34 were constructed as typical activities by spacecraft area and metabolic rates for space missions. Of the principal factors affecting human comfort, dry-bulb temperature carries the greatest weight in maintaining the comfort zone. This is due to the fact that for any specific pressure or gas composition, the dry-bulb temperature must be held to the optimum value plus or minus 5°F. Dry-bulb temperature is also the determining factor for the relative humidity of the environment.

Table 3-33. Metabolic Rate for Space Activities in Zero-g

Activity	Metabolic Rate Range (Btu/hr)	Metabolic Rate Nominal (Btu/hr)
Assembling parts	800 - 1000	900
At lecture	400 - 800	600
Changing clothes	600 - 900	750
Cooking	600 - 1000	800
Eating	350 - 550	450
Electrical assembly	800 - 1200	1000
Electronic repair	500 - 700	600
Exercising	1200 - 2200	1700
General office	500 - 900	700
Machining	550 - 750	650
Monitoring systems	350 - 650	500
Playing games (cards, chess, pool)	400 - 650	525
Sheet metal work	1000 - 1750	1375
Sitting at rest	300 - 500	400
Sleeping	250 - 350	300
Strenuous sports	1800 - 2800	2300
System checkout	500 - 1000	750
Transporting cargo	800 - 1600	1200
Typing	500 - 700	600
Walking	650 - 950	800
Washing	700 - 1300	1000
Watching/Listening, Entertainment	300 - 500	400
Welding	550 - 750	650
Writing	350 - 550	450

Table 3-34. Area Activities in Vehicle

Area \ Activity	Sleeping	Eating	Monitoring systems	Sitting at rest	At lecture	Typing	Cooking	Assembling parts	Walking	Exercising	Transporting cargo	Changing clothes	Strenuous sports	General office	Welding	Sheet metal work	Electrical assembly	Machining	Electronic repair	System checkout	System operation	Writing	Playing games	Entertainment	Washing
Living Areas																									
Lounge				X					X													X			
Recreation				X					X													X	X	X	
Passageways									X		X														
Study or library				X																		X			
Bedroom	X								X			X													
Bathroom									X			X													X
Classroom					X																	X			
Food Preparation and Serving																									
Kitchen							X		X																
Dining room		X		X					X																
Food storage									X		X														
Snack bar		X							X																
Services																									
Laundry			X						X		X														X
Briefing room					X				X													X			
Locker room									X		X														X
Theater				X					X															X	
Dispensary									X		X											X			
Chapel				X																					
Barbershop				X					X												X				
Supply									X		X														
Maintenance			X					X	X		X					X	X		X	X					
Equipment								X	X		X									X					
Gym									X	X			X												
Power			X						X								X			X					
Work Areas																									
Control room			X						X												X	X			
Airlocks									X		X														
Inspection			X						X											X					
Photographic support									X		X											X			
Animal housing									X		X											X			
Dock									X		X														
Agricultural study									X		X											X			
Computer			X			X															X	X			
Offices						X			X					X								X			
Laboratory			X						X												X	X			X
Shops								X	X		X				X	X	X	X	X						
Communications			X																		X				

Next to dry-bulb temperature, the gas flow rate has the most effect on the human comfort zone. This effect is graphically shown in Figure 3-23. As can be seen from this graph, at the optimum gas flow rates of 30 to 80 fpm and on the low temperature side of the comfort zones, a change of 10 fpm in gas velocity results in an approximately 5°F change in temperature. The rate of temperature change on the high side of the comfort zone is much less due to the sensation that increasing the gas velocity has a cooling effect and movement of the warmer gas does not create as great a change in the feeling of coolness as does the cooler gas.

Since gas velocity ranks second only to temperature in air conditioning, it was reasoned that if the same mass of gas at a given temperature flows past the crew member in a given time period, the amount of heat removed or added to the crew member could be directly correlated to the sea level comfort zone. This is assuming the gas behaves like an ideal gas. Gases at the low pressures of the spacecraft do behave as ideal gases and the relationships were worked out using the perfect gas law, $P = \rho RT$ and the general energy equation $Q = hA(T_g - T_A)$. The gas constants (R) for the gases were determined by dividing the molecular weight of the gas composition into the universal gas constant, 1545. The molecular weight of the gas composition is found by taking the percentage of each part and multiplying the percentage times the molecular weight of that part and adding the two together. With the gas constant known, the density of the composition can be found.

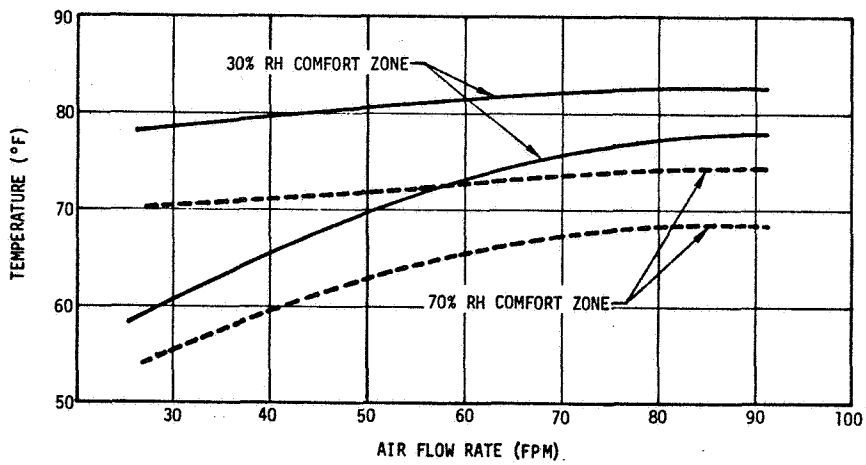


Figure 3-23. Air Velocity Effects on Human Comfort Zones

Sample Calculation

O_2-N_2 gas at 5 psia, and O_2 partial pressure of 3.07 psia

Find: Gas Composition Constant (R)

Known Factors: Molecular Weight of Oxygen = 32

Molecular Weight of Nitrogen = 28

Step 1) Calculate the percentage of Oxygen = $\frac{3.07 \text{ psia}}{5 \text{ psia}}$ = 61% O_2

Therefore percentage of Nitrogen = 100% - 61% = 39% N_2

Step 2) Calculate molecular weight of composition = (61%)(32) + (39%)(28) = 30.44

Step 3) Gas Constant (R) = $\frac{\text{Universal Gas Constant}}{\text{Molecular Weight of Composition}}$ =

1545 ÷ 30.44 = 50.76

Note: For an oxygen-helium composition at 5 psia, repeat 2 and 3 but use the molecular weight of Helium (4) instead of the molecular weight of nitrogen.

3.4 COLOR

3.4.1 Requirements. Color will be used to provide visual stimulation for the occupants and to create different moods for relieving the monotony of prolonged confinement. Factors required in color planning are: room volume, function, and desired behavioral aspect.

3.4.2 Definitions.

Hue - The property that distinguishes one color from another; e.g. green from blue.

Intensity - The quality which indicates the degree of color strength of hue. As a color is muted or softened by the addition of its own complement on the color wheel, its intensity diminishes.

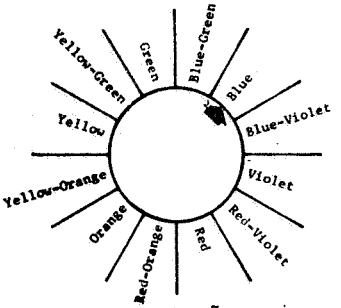
Value - The degree of lightness or darkness of the color relative to a white to black scale.

Dominant Hue - The general overall color of the area, or the largest color application.

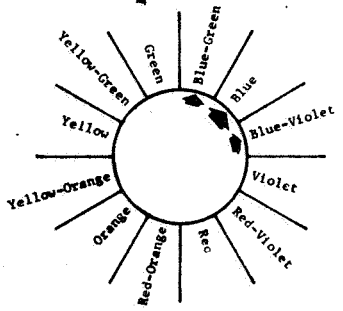
Subdominant hue - The second largest color application.

Subordinate hue - Those colors used to accent the dominant and subdominant hues.

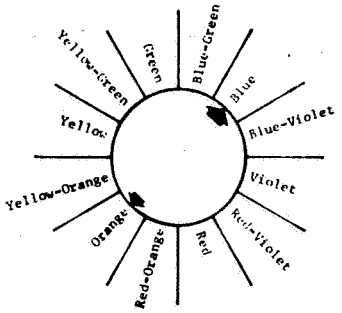
Monochromatic Color Scheme - A scheme utilizing one spectral hue, e.g., blue in varying values and intensities.



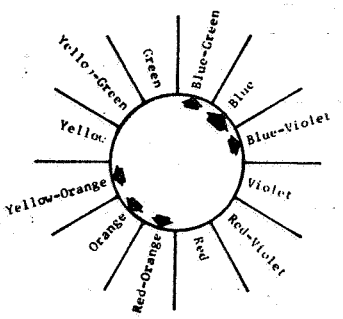
Analogous Color Scheme - A scheme utilizing two or more hues next to each other on the spectrum, e.g., blue with blue-green or blue-violet.



Monochromatic or Analogous Schemes with Complementary Color Accents - The basic monochromatic or analogous color scheme utilizing the complementary color(s) of the basic hue(s) as an accent. (See sketch on next page.)



Monochromatic
Complementary



Analogous
Complementary

Quality - The three factors which determine the quality of a color (hue, intensity, and value) can make a room look expansive or cramped, dark or light, and calm or exciting.

3.4.3 Engineering Data.

3.4.3.1 Hue. Most good color schemes consist of no more than three hues. Use of warm or cool hues is determined by the function of the room involved. Warm hues are associated with extroverted responses and feelings. Where it would be beneficial to emphasize feelings of extroversion, e.g., an area in which social contact is implicit to the function of the area, usage of warm hues will maximize these feelings, usage of cool hues will minimize them. Warm hues generally should be used if the temperature of the room is cool, the noise element is low, the room size is too large, texture is smooth, physical exertion is light, time exposure is short, a stimulating atmosphere is desired and lamps are fluorescent (cool). The introverted response is associated with cool hues. Where a contemplative atmosphere is dictated by the function of the area, cool hues will add emphasis; warm hues will dilute this type of atmosphere. Cool hues should generally be used when the temperature is warm, the noise element is high, room size is too small, texture is rough, physical exertion is heavy, time exposure is long, a restful atmosphere is desired and lamps are incandescent or fluorescent (warm).

3.4.3.2 Intensity. Color intensity induces two basic mental sets which may be described as centrifugal and centripetal. A centrifugal mental set is one in which an individual's attention is directed outward. High color intensity and high levels of illumination as well as warm hues evoke this set to its highest degree. Conversely, the centripetal mental set directs an individual's attention, inward. Low color intensity and low

illumination as well as cool hues maximize the centripetal mental set.

Intense colors will be used primarily as accent colors. Intense colors should be used if time exposure is short, concentration is low, noise level is low, and a stimulating atmosphere is desired. Muted (less intense) colors should be used where time exposure is long, concentration high, noise level is high, and a restrained atmosphere is desired.

3.4.3.3 Value. The desired level of illumination should be kept in mind when determining the color value of a room. Light color values should be used if a high level of illumination is required as dark values tend to produce a low level of illumination.

Contrast within a room is achieved by using light values with dark values. Contrast should be low if time exposure is long, room size is small, a restrained atmosphere is desired and wall surfaces are textured. Contrast should be higher if time exposure is short, room size is large, an exciting atmosphere is desired and wall surfaces are flat.

As a color is grayed, the further it appears to be from the eye of the observer. Atmospheric perspective conditions the eye to perceive gray colors in this manner and this natural phenomenon is retained by the observer in artificial environments. Thus, color value can be used to visually enlarge a space.

3.4.3.4 Dominant Hue. The dominant hue in most cases will be the wall color, and is generally the lightest in value. Ceilings are usually white or off-white in the direction of the dominant hue.

3.4.3.5 Subdominant Hue. The subdominant hue is of a higher intensity of deeper value than the dominant hue, and is applied to the second largest surface (generally floor surfaces). The subdominant hue will usually be of the same hue or adjacent to the dominant hue on the color wheel.

3.4.3.6 Subordinate Hue. Subordinate hues will be used on furnishings, accessories, or as accent colors in areas relative to the space involved. Two or more subordinate colors may be used but a judicious use of the colors is recommended. The subordinate hues are of a higher intensity of deeper value than the dominant and subdominant hues. They may be of the same hue, or adjacent or opposite to the dominant hue on the color wheel.

3.4.3.7 Monochromatic Color Schemes. Monochromatic schemes tend to be dull to the observer and should generally be avoided, but they serve well in storage areas and the like. They should also be considered in areas where relief from an effect of color saturation exists.

3.4.3.8 Analogous Color Schemes. Analogous schemes (those utilizing colors adjacent on the color wheel) create low key interest, due to the subtle differences inherent in this type of scheme. This scheme is recommended for areas where relaxation and reflection are desired.

3.4.3.9 Monochromatic or Analogous Color Schemes with Complementary Accents. The greatest range of contrast and interest is available through the use of complementary color accents to either the monochromatic or analogous color schemes. Care should always be exercised in maintaining a pleasing balance between these accent colors and the basic color scheme.

When complementary accents are employed, no more than three hues should be considered; most often a single hue varying in intensity or value is the most effective. The use of complementary color accents can control the degree of excitement in any given space. A broad application of complementary colors creates more excitement than a limited application.

3.4.4 Color Effects. The association of colors with definite mental conditions and moods is general. No absolute relationships have been established, and the subject is open to individual interpretation. However, research has shown that certain general reactions are common to most people. Thus, yellow is considered a warm color and blue a cool color.

Obviously, reflectance values of colors are important in planning areas where sight requirements are high; low reflectance values are sufficient where sight is not an important requirement in the accomplishment of work tasks. Reflectance values should therefore be considered in these areas.

Colors affect perception of space and are capable of creating different feelings and moods. Color also affects the apparent size of objects and their position in space. Warm colors (reds, oranges, yellows) are advancing colors, and cool colors (blues, greens, purples) seem to recede in space. As these hues are muted their effects upon position diminish.

When a small colored area is surrounded by other colors, intense red is the most advancing color and dark blue and black are the most receding.

When color is applied to a large area such as the walls of a room, black and dark red are the most advancing colors; white and light blue are the most receding colors. Intense colors mixed with black tend to advance, making rooms seem smaller; intense colors mixed with white tend to recede making a room seem larger.

3.4.5 Application.

3.4.5.1 Reference. Color schemes as presented herein have been developed from the Ostwald Color System. This system is broadly used, but is by no means intended as a sole source. As with any system, there are certain inherent limitations in expressing all nuances of color. Color variants which present themselves at various design stages should be handled on an individual basis.

3.4.5.2 Usage and Implementation. In an actual working situation, an activity area (particularly a combined activity area) must be thoroughly defined in terms of mood(s) desired prior to selecting a color scheme. Table 3-35 has been developed to define, in general terms, desirable and undesirable moods in various areas. Table 3-36 can then be employed to select the hue which will best evoke the desired mood.

Having assigned a hue, the intensities and values should be considered. High intensity hues are used to create a stimulating atmosphere and low intensity hues are used to create a relaxed atmosphere (see paragraph 3.4.3.2). The value of the hue to be applied will be dependent primarily upon the level of illumination required. The use of light values with dark values creates contrast. Value contrast should be high for areas where an exciting atmosphere is desired and low for areas where a dignified or relaxed atmosphere is desired (see paragraph 3.4.3.3).

The color schemes presented are intended to serve as a guideline only. These do not represent specific standards but are generally acceptable color schemes for the designated areas. Monochromatic and analogous color schemes are included; in addition, complementary color accents are provided for both schemes.

Table 3-35. Effects of Color Upon Habitable Areas

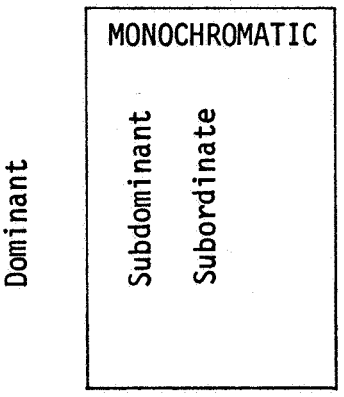
	Exciting	Stimulating	Cheering	Neutralizing	Retiring	Relaxing	Subduing	Depressing
Private								
Crew compartments			X	0		X	0	0
Public								
Dining room			X			X	0	0
Lounge			X			X		0
Recreation	X	X						0
Library	0	0		X		X	X	0
Study	0			X	X			0
Conference		X						0
Passageways				X			0	0
Chapel	0	0			X	X	X	0
Gym	X	X			0	0	0	0
Locker room			X		0	0	0	0
Theater		X					0	0
Briefing room		X					0	0
Service								
Galley			X					0
Snack bar			X	0				0
Bathroom		X	X	X		X		0
Dispensary			X			X		0
Laundry				X				0
Barbershop			X			X		0
Work								
Equipment				X				0
Maintenance				X				0
Power				X				0
Storage, food				X				0
Supply				X				0
Control room	0	0		X				0
Communications	0	0		X				0
Computer	0	0		X				0
Shop	0	0		X				0
Offices	0			X				0
Laboratories	0			X				0
Dock	0			X				0
Photographic support				X				0
Animal housing				X				0
Agri. study area				X				0
Air locks	0			X				0

Legend: X = Desirable effect
0 = Undesirable effect

Table 3-36. Effects of Hue

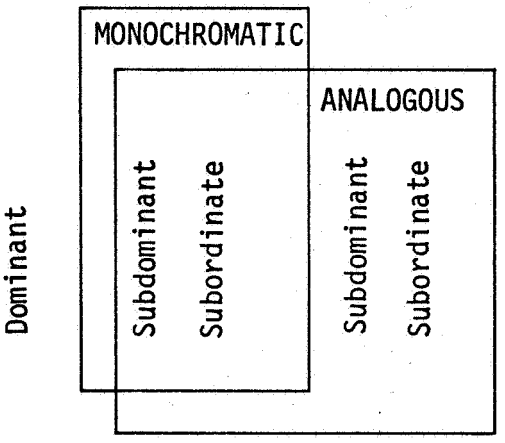
Effect	Hue	Contrast
Exciting	Bright red Bright orange	High
Stimulating	Red Orange	Moderate
Cheering	Light orange Yellow Warm gray	Moderate
Neutralizing	Gray White/off-white	Low
Retiring	Cool gray Light green Light blue	Low
Relaxing	Blue Green	Low
Subduing	Purple	Moderate
Depressing	Black	Low

3.4.5.3 Monochromatic Color Scheme. The monochromatic color scheme consists of the dominant color, the subdominant color and no more than three of the subordinate colors.

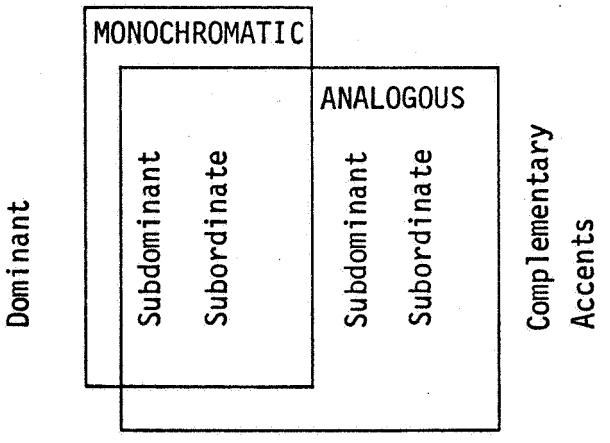


3.4.5.4 Analogous Color Scheme. The analogous color scheme utilizes the same dominant color; the subdominant color may be selected from either the

monochromatic scheme or from the analogous scheme. Subordinate colors may be selected from either category, as well. (Subdominant and subordinate colors may be intermixed in any combination to produce an analogous color scheme). Obviously, selection of colors solely from the monochromatic category would result in a monochromatic scheme.



3.4.5.5 Complementary Color Accents. Complementary color accents are provided for both monochromatic and analogous color schemes. Selection of these accent colors should be made with great discretion and should never exceed three in number.



3.4.5.6 Identification by Color. The United States of America Standards Institute recommends that the following colors be utilized in connection

with accident prevention, the marking of physical hazards, the location of safety equipment, and the identification of fire and other protective equipment, etc.

Red shall be the basic color for identification of:

(1) Fire protection equipment and apparatus
(2) Danger
(3) Stop

Orange shall be used to designate exposed unguarded hazards, such as:

(1) Inside of transmission guards for gears, pulleys, chains, etc.
(2) Exposed parts (edges only) of pulleys, gears, rollers, cutting devices, power jaws, etc.
(3) Safety starting buttons

Yellow shall be the basic color designating caution, such as:

(1) Waste containers for explosive or highly combustible materials
(2) Caution signs
(3) Piping systems containing dangerous materials

Green shall be used as the basic color designation for safety and the location of first aid equipment.

Blue shall be the basic color for designation of caution limited to warning against the starting, the use of, or the movement of equipment under repair or being worked upon.

Purple shall be the basic color for designating radiation hazards, such as:

(1) Rooms where such material is stored or handled
(2) Disposal cans for radioactive material
(3) Contaminated equipment
(4) Signal lights which indicate when radiation-producing units are in operation

Color coding standards for marking fluid lines and valves for military equipment are as follows:

Red:	Fuel
Green, Gray:	Rocket oxidizer
Red, Gray:	Rocket fuel
Red, Gray, Red:	Water injection
Orange, Green:	Inerting
Yellow:	Lubrication
Blue, Yellow:	Hydraulic
Orange, Blue:	Pneumatic
Orange, Gray:	Instrument air
Blue:	Coolant
Green:	Breathing oxygen
Brown, Gray:	Air conditioning

Yellow, Orange:	Monopropellant
Brown:	Fire protection
Gray:	De-icing
Yellow, Green:	Rocket catalyst
Orange:	Compressed gas
Brown, Orange:	Electrical conduit
White:	All other

The Interstate Commerce Commission requires that dangerous products be marked in the following manner when being shipped.

Red letters on white background:
(1) Poisons
(2) Explosives
(3) Poisonous gases
(4) Tear gas

Black letters on green background:
(1) Compressed gases

Black letters on red background:
(1) Flammable liquids

Black letters on yellow background:
(1) Flammable solids
(2) Oxidizing materials

Black letters on white background:
(1) Acids

In addition to the above lists, many color codes exist within specific industries for designation of certain materials and operating conditions.

3.5 VOLUME

3.5.1 Requirements. This section defines the minimum desirable volume for specific activities as related to mission parameters. Specifically, the data addresses itself to developing standards for extraterrestrial habitats, in which the average person could work, sleep, eat and relax comfortably and efficiently over long periods of time.

Insufficient data exist to determine exact minimum desirable standards; therefore, the reader must recognize that the volumetric recommendations developed should be used as guidelines and do not represent fixed standards.

It is probable that within any randomly selected, highly talented group of professionals, a high percentage of dominant types would exist. Confining such a group in very tight quarters could possibly lead to considerable interpersonal stress. It is because of these potentially stressful situations that the adequate and appropriate division of space becomes so critical. This is not to say that adequate volume alone will make a space habitable.

A factor which can be affected by the designer is the monotony of the environment. This sensual boredom seems to have less to do with volume of space (assuming a baseline of acceptability) than it does with the treatment and geometry of that volume; the boredom that sets in after an extended period of confinement can be alleviated by the designer providing for some degree of change in the physical environment of the habitat.

As a general rule, it is recommended that volumetric provisions for individual activity areas, such as dining and sleeping, increase in a direct arithmetic progression in relation to the number of crewmen using the area. In other words, a dining room designed to seat 15 crewmen should double in size to seat 30 crewmen in a similar fashion.

3.5.2 Definitions.

Gross Area - Gross area is the approximate area required to attain the minimum tabulated net area. Gross area is found by deducting only large ventilation trunks, access trunks and other similar items. No deduction should be made for normal access ladders or main passageways within the space. This area represents the entire wall to wall area.

Area per Man - Area per man refers to the numerical figure arrived at by dividing the gross area of a space by the number of occupants the space is designed to hold.

Net Area - Net area is defined as deck area that can actually be walked upon. Deck area occupied by trucks, hatches, fixed berths, lockers, installed furniture, etc., are excluded.

Visual Space - Visual area is the amount of space visually perceived as usable. This space is related to physical objects in a room, e.g., furniture and partitions, and the placement of these objects relative to the observer's eye level (sitting and standing). For example, a 7 foot long by 3 foot wide by 5 foot high bunk bed placed against the wall in a 7 foot by 7 foot by 7 foot room appears to make the room look smaller. On the other hand, a single low bed 7 feet long, 3 feet wide and 18 inches high, placed against the wall in the same 7 by 7 room does not significantly reduce the visual area of the room.

Room and Furnishings	Area (ft^2)		
	Gross	Net	Visual
7 X 7 No furniture	49	49	49
7 X 7 Low Bed	49	28	49
7 X 7 Bunk Bed	49	28	28

Minimum Desirable Volume - That volume provided for a specific activity which man will perceive as adequate. A minimum desirable volume provides adequate space to support the dynamic envelope man describes in performing the activities related to that space, the volume in which man feels comfortable in regard to distance between himself and others, and the volume which man visually perceives as adequate during all activity conditions.

3.5.3 Engineering Data.

3.5.3.1 Gross Area. Gross area represents the total area occupied by an activity and is useful in tabulating the overall station volumetric requirements. Because gross area takes in all of the area occupied by built-in furniture, storage units and the like, it is not a useful figure for visualizing the usable area in space.

3.5.3.2 Area Per Man. Since this figure relates to the number of occupants a space is designed for, it is useful in figuring area requirements for public areas and other areas in which the number of occupants determines the spatial requirements of the room.

3.5.3.3 Net Area. This figure is especially relevant in those areas which are occupied for extended periods of time and are of limited size, e.g., offices and private quarters.

3.5.3.4 Visual Area. Like the net area, this area consideration is especially important in small areas in which people are likely to spend a considerable amount of time, such as private quarters and office space.

3.5.3.5 Minimum Desirable Volume. The perception of space as adequate, small, large, etc. is a subjective response to an area based on a number of factors, among them being:

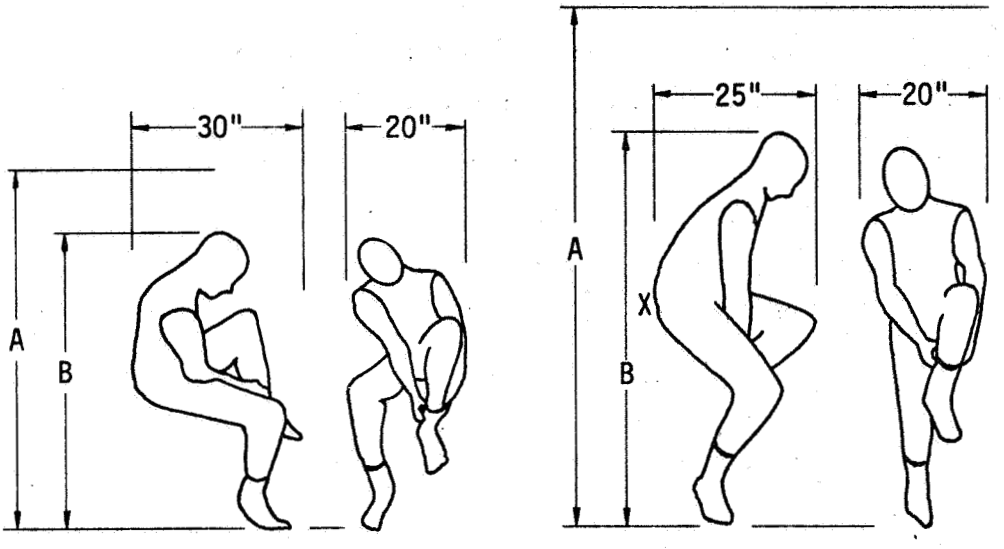
- Kinesthetic response
- Interpersonal or social response
- Visual response

3.5.3.5.1 Kinesthetic/Anthropometric Spatial Requirements - Kinesthetic and anthropometric spatial requirements refer to the size and shape of a space required to contain both "point" and "transfer" body movements related to specific tasks in both an artificial gravity and a zero gravity environment.

Point Movement - That movement occurring at a fixed point of restraint or positioning such as movement related to the act of putting on a pair of socks as illustrated in Figure 3-24. Point movement spatial requirements established in a gravity environment will most likely prove sufficient in zero gravity. However, as illustrated in Figure 3-24, point movement spatial standards established in a gravity environment may prove to be below minimum in some cases if used to establish zero-gravity spatial standards.

Transfer Movement - That movement occurring during bodily transfer from one point to another. Each type of activity requires that a certain amount of space be provided to contain the related movements. It is this type of movement which determines minimum widths for passageways and establishes the minimum distance between chair backs in a dining area.

Putting on Socks - 50th Percentile

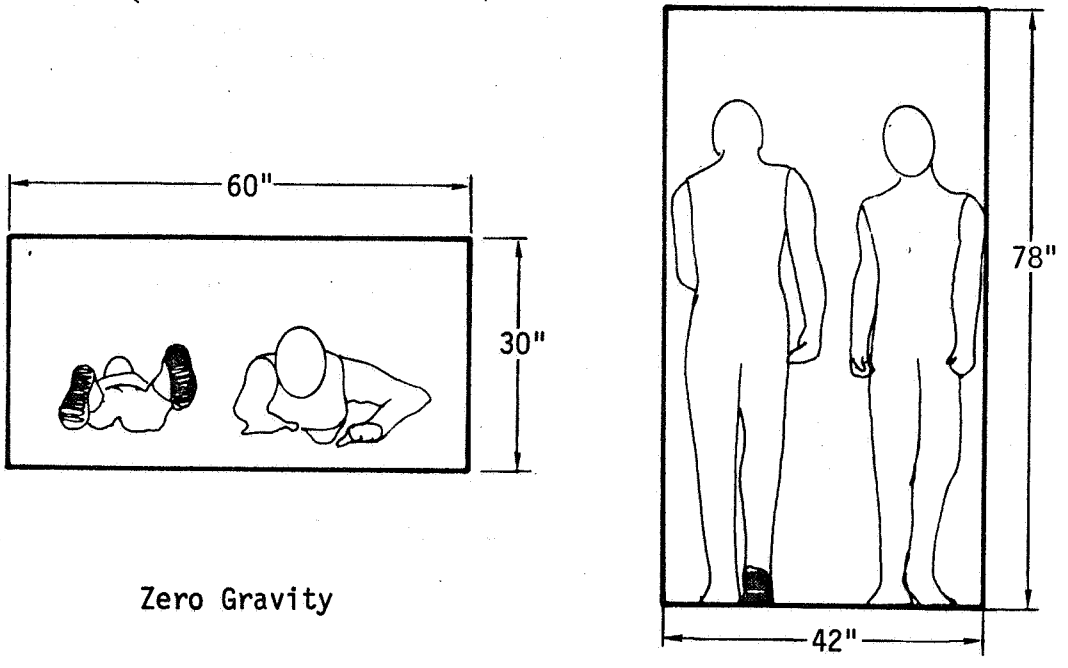


Seated - Artificial Gravity
A-54" Seated Erect
B-45" Seated Crouched

Waist Restraint - Zero Gravity
A-70" Standing Erect
B-60" Standing Crouched
X - Point of Restraint

Figure 3-24. Point Restraint Area Comparison

As illustrated in Figure 3-25, an enclosed 30 inch by 60 inch passageway will be sufficiently large for two way traffic in a zero-gravity environment. This represents a 45 percent reduction in volume over an acceptable artificial gravity two-way passage. For extended open area transfer, to facilitate what appears to be the most natural type of movement (head first "push off and glide"), and to minimize the possibility of collision between people in motion and people restrained, straight aisles 30 to 60 inches wide should be provided between all obstacles such as restrained people or tables. This degree of table separation in areas such as the dining room has the additional benefit of maintaining a degree of audio privacy between tables.



Zero Gravity

Artificial Gravity

Figure 3-25. Passageway Area Comparison

While it is not recommended that traffic be directed overhead, it is recognizable that traffic patterns should be high enough to allow individuals to pick up visual cues for seat selection. This is illustrated in Figure 3-26.

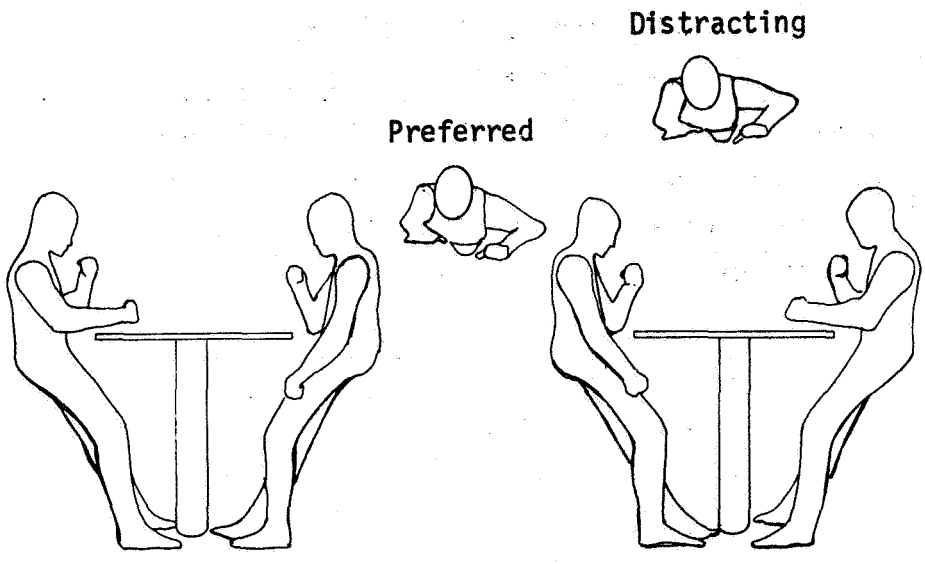


Figure 3-26. Zero Gravity Open Area Transfer

3.5.3.5.2 Social Spatial Requirements - These standards have been established so that interpersonal contact may occur at the social range which is comfortable to individuals in our society. It is felt that contact at personal and intimate distances should be a matter of choice rather than an imposed necessity.

3.5.3.5.3 Visual Spatial Requirements - A space will usually be visually perceived as adequate if sufficient room is provided for movement and comfortable social interaction.

3.5.4 Volumetric Effects.

3.5.4.1 Privacy of Crew Quarters. Crew quarters designed to accommodate more than one crewman must take into careful consideration the psychological factors of individual behavioral patterns. A fundamental need in man appears to be the provision for territoriality, or in other words,

furtherance in the concept of possession of property and rights of ownership. If the function of the personal quarters is to serve more than simply a place to rest during off-duty hours, it must take into account these human reactions. The term personal quarters must be uniquely personal in the sense that this specific volume of space belongs to a specific individual. Active and outgoing personalities in opposition to introspective types can create untenable reactions that could have disruptive effects on the entire crew morale.

The best arrangement is to provide individual personal quarters for each crew member, even at the cost of a reduced spatial enclosure. The rooms should provide a minimum of approximately 38 square feet of visual area (at any level). This is based on the premise that the crew quarters support the following six activities: sleep, private relaxation, limited social relaxation, personal work, personal storage, and limited grooming. Depending on the arrangement of the room, the gross area requirement would be about 45 to 50 square feet (at deck level).

When there is no alternative but multiple occupancy in personal quarters, the number of crew should be in even increments rather than odd, i.e., 2, 4, 6, 8, rather than 3, 5, 7, 9. Group studies have indicated that these even patterns reduce the chance of the "Odd Man Out" condition to occur. It is essential that partitions or curtains be provided that ensure privacy as well as territorial definition of the individual's personal space.

The following gross areas provide each individual in the room with the same furniture and storage equipment that he would have within a private room. Additional spatial economy could be realized by reducing individual furniture standards. For instance, the desk could be shared by two people.

Men/Room	Square Feet/Man (Gross)
1	45-50
2	38
3	42
4	36
5	40
6	39
7	40
8	39
9	42

3.5.4.2 Volume Related to Responsibility Level. The data in this volume are based on the crew being organized into three levels of responsibility; command, line officers, and working crew. The volumes of the private facilities for individuals at each level are given in Section 2 and Table 3-37. The commander's office and bathroom are to be located adjacent to his private room, and because of their accessibility, they will be considered a part of the commander's personal space.

Depending on the size of the crew, the deputy commander and line officers should be provided with direct access into semi-private or private bathroom facilities located adjacent to their bedrooms.

3.5.4.3 Spatial Needs as Related to Crew Size and Mission Duration.

3.5.4.3.1 Individual Activity Spatial Needs - As a general rule, the space provided for individual activities such as dining and sleeping is increased in a direct arithmetic progression in relation to the number of crewmen using the space. In other words, a dining area which was designed to seat 15 crewmen would double in size to seat 30 crewmen in a similar fashion. However, the space would not change in size as the mission duration changes. In this case, a dining area which is considered as desirable for a 60-day mission would remain so for a 180-day mission.

3.5.4.3.2 Total Habitat Spatial Needs - The space in the overall habitat should be increased as a result of a significant increase in mission duration and should be more than a direct arithmetic increase in space due to a significant increase in crew size. This increased need is illustrated in Figure 3-27. The reason for the increased habitat spatial area is that there exists an increased need for compartment specialization as crew size and/or mission duration increase. This splitting off of activities into separate compartments results in an increased level of sensual stimuli which is required by extended mission duration. This also reflects the increased activities for larger crews.

For example, an area in a 20-man habitat which primarily supports the activities of lounging, training conferences, theater, passive recreation and snacks, will become less effective as mission duration increases (same sized crew) or as the crew size increases. The historical trend for habitat

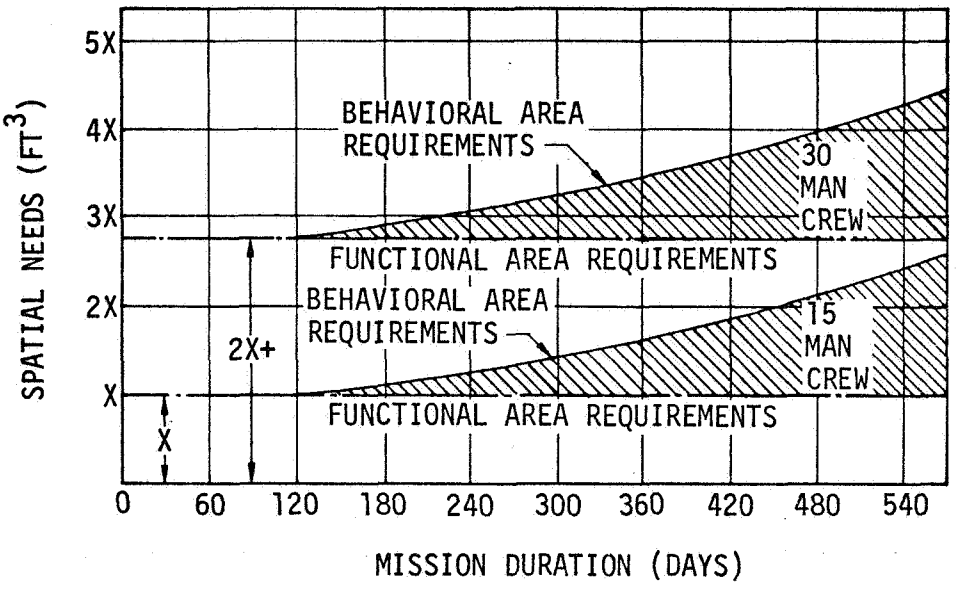
Table 3-37. Room Height, Area, Volumes

Habitability Unit	Ceiling Height (ft)	Gross Area Per Man (ft^2)	Gross Volume Per Man Artificial Gravity (ft^3)	Gross Volume Per Man Zero Gravity (ft^3)
Bedroom-One man	6.5	50	325	220***
Bedroom-One man with bath	6.5	80	520	400***
Bedroom-Two men with bath	6.5	70	455	440***
Bedroom-One man with office and bath	6.5	133**	865	650
Dining room	7.0*	15	105	90
Lounge	7.0	16	112	90
Recreation	7.0	10	70	70
Library	7.0	10	70	70
Study	6.5	10	65	70
Conference	7.0	15	105	90
Passageway (2 way)	6.5	*	-	-
Chapel	6.5	15	98	90
Gym	7.0	10	70	70
Locker room	6.5	*	-	-
Theater	7.0	12	84	78
Briefing room	6.5	15	98	90
Galley	6.5	*	-	-
Snack bar	6.5	*	-	-
Bathroom-toilet, lav. and shower (single occupancy).	6.5	34	221	180
Dispensary-single patient occupancy	6.5	86	559	500
Laundry	6.5	*	-	-
Barbershop	6.5	43	280	280
Equipment	*	-	-	-
Maintenance	*	-	-	-
Power	*	-	-	-
Food storage	6.5	*	-	-
Supply	6.5	*	-	-
Control	6.5	*	-	-
Communications	6.5	*	-	-
Computer	6.5	*	-	-
Shop	*	*	-	-
Offices	6.5	38**	247	247
Laboratories	*	-	-	-
Dock	*	-	-	-
Photographic support	*	-	-	-
Animal housing	*	-	-	-
Agriculture study area	*	-	-	-
Air locks	*	-	-	-

* Varies with mission parameters, see Section 2 ** 31-60 men crew size
***Visual volumes of 247 ft^3, minimum, may be shared

Note: The volumes listed are on a gross per man basis. They are derived by using the full dimensions from wall to wall and floor to ceiling and then dividing by the number of crewmen using the room at one time.

activity areas to become increasingly specialized as mission duration and/or crew size increase is discussed in Section 4.3 on Dual Room Usage.



Increased Behavioral Area Due to Specialization.
NOTE: Specialization refers to physical separation of activities which may have formerly occupied a "Dual Room Usage" area.

Figure 3-27. Overall Habitat Volumetric Requirements as a Function of Crew Size and Mission Duration

3.5.4.4 Effect of the Location of Living Quarters to Work Area. The crew compartments should be located away from the work areas for the following reasons:

- Enforced social interaction - Locating the personal quarters at a distance from the work area will have the effect of combating any tendency for individual isolation to occur by forcing individuals to pass through other activity zones.

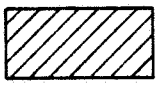
- Provide change of environment - Variety of spatial experience that should occur during transit from one area to another is desirable as sensory stimuli providing the "change of pace" between the schedule of activities.

The determining factor of proximity between an individual's crew compartment and his work station should be based on:

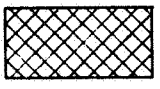
- Responsibility for critical decision making
- Under emergency conditions, the minimal time limitations for decision making.

These factors will have to be determined according to the individual requirements of station configuration, crew size, and mission responsibility.

3.5.5 Application. The volumetric standards given in the Architectural Design Criteria section (Section 2) may be utilized in the early planning stages to establish approximate volumetric figures for the off-duty areas only. It should be realized that these figures are based on rectangular shaped rooms. Because of the unusual geometry of some of the spaces resulting from the relationship of the space to the vehicle pressure shell, the desirable gross area recommendations will not always prove sufficient. Additionally, the degree of spatial efficiency and the resulting volume of dual room usage combinations must be studied on an individual mission basis to accurately determine acceptable area standards. Ideally, these combinations should be studied in full scale mock-ups to evaluate the spatial adequacy under all conditions of occupancy. To aid in the development of graphic layouts, select pieces of furniture are illustrated on the following pages with acceptable standard dimensions where appropriate (See Figure 3-28). In addition to the furniture dimensions, the related net or clear floor area is also shown as illustrated below. These figures may be used to develop dimensionally acceptable furniture relationships within the area being studied.



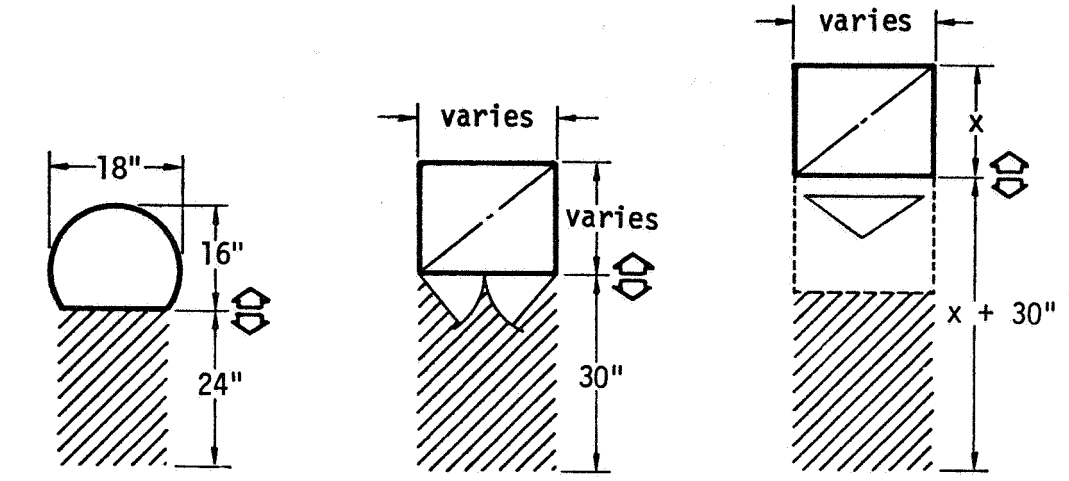
Clear floor area required relative to furniture elements (no passageway considerations).



Clear floor area required relative to furniture elements (passageway area).

No attempts have been made to specify exact furniture standards to be used in extraterrestrial habitats. The information provided is of a fairly general nature and is based on only those basic units commonly found in an off-duty section of any habitat.

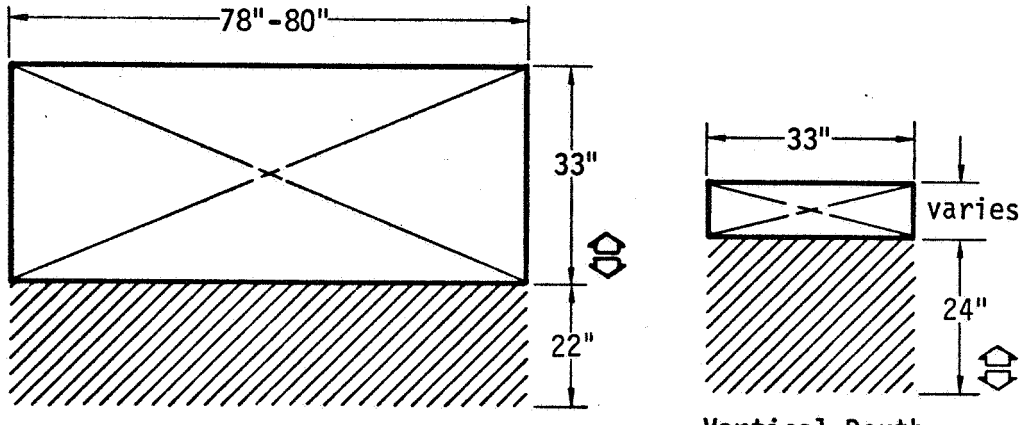
For artificial gravity layout studies, arrows indicating the desirable direction of spin relative to furniture units are shown to the right of appropriate units.



Desk Chair
15"-17" height

Cabinet Storage

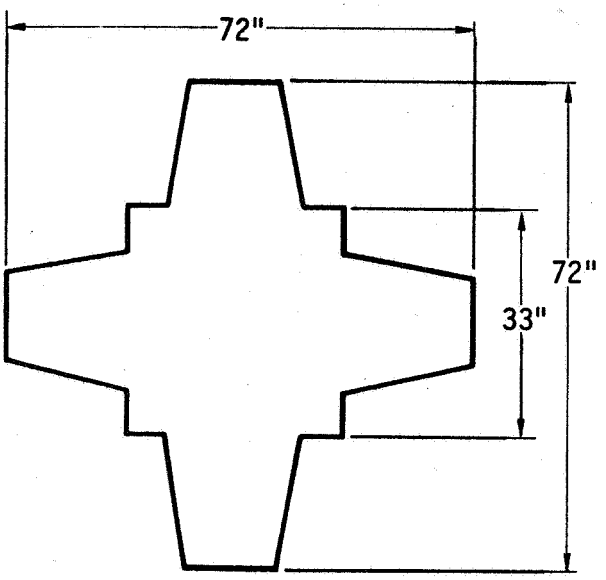
Drawer Storage



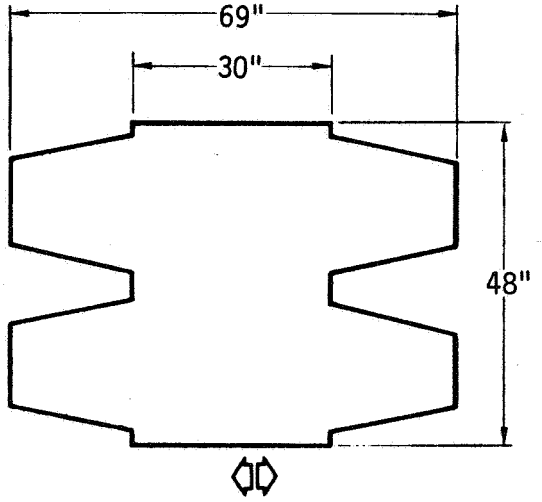
Berth
18" height

Vertical Berth
(Zero-g only)
70"-80" height

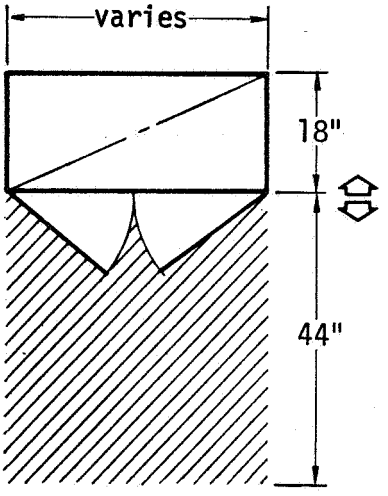
Figure 3-28. Furniture Graphic Symbols (Page 1 of 4)



4-Man Table
(Non-Coriolis)
30" height

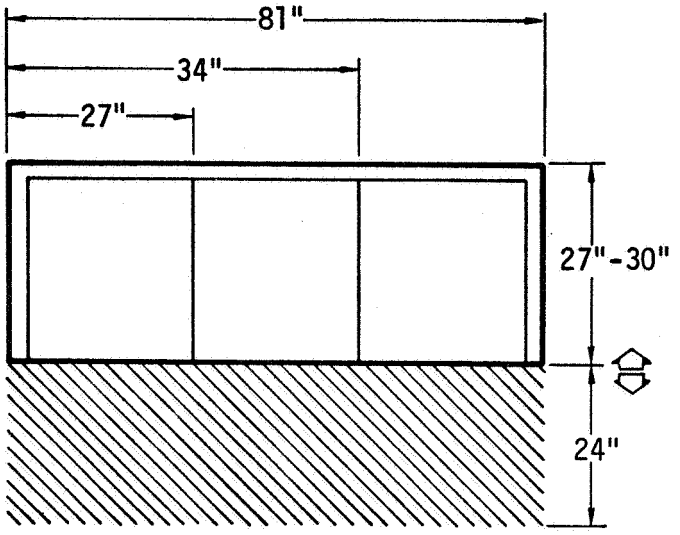


4-Man Table
(Coriolis)
30" height

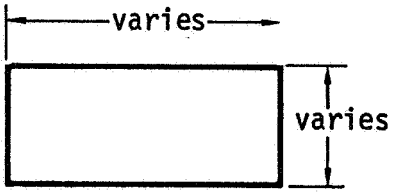


Storage Buffet/Serving Table
30" height

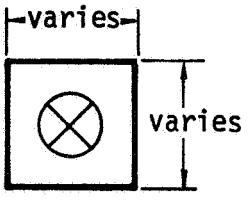
Figure 3-28. Furniture Graphic Symbols (Page 2 of 4)



1-3 Man Seat
15"-17" height

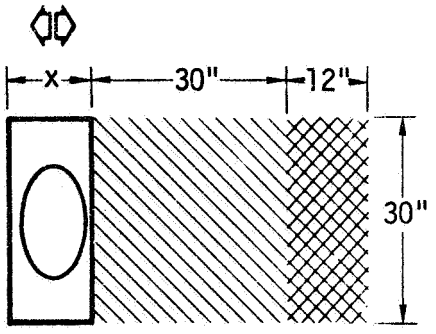


Varying Length Coffee Table
14"-16" height

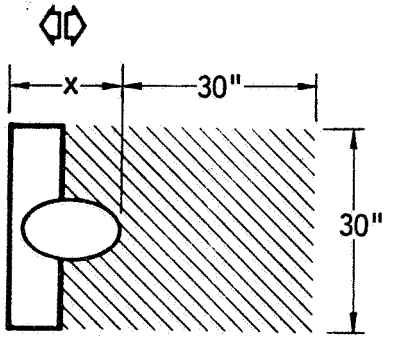


End Table
15"-20" height

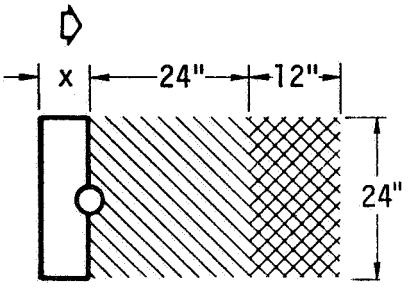
Figure 3-28. Furniture Graphic Symbols (Page 3 of 4)



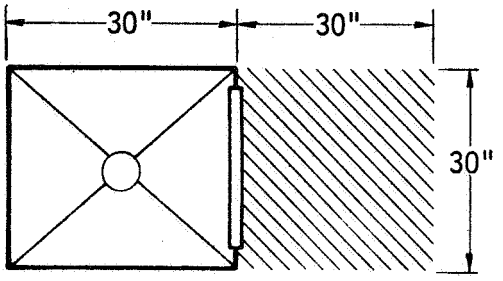
Lavatory
34"-38" height



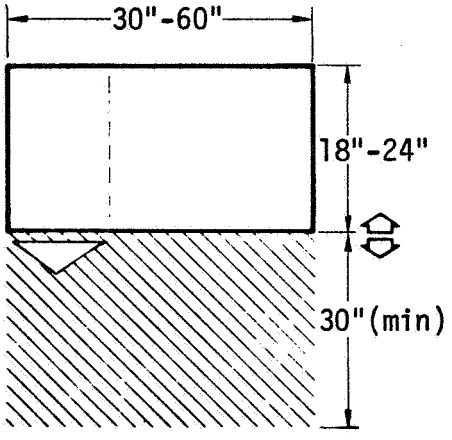
Toilet
9"-13" height



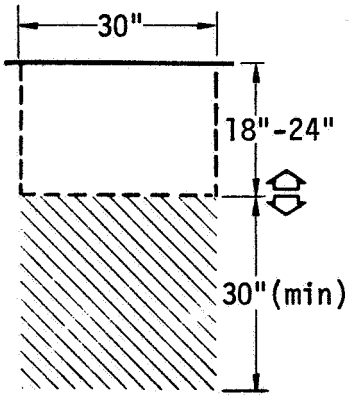
Urinal
24" height



Shower



Desk with Drawer or File
30" height



Folding Desk
30" height

Figure 3-28. Furniture Graphic Symbols (Page 4 of 4)

4.0 RELATED ENVIRONMENTAL ELEMENTS

This section provides the designer with a general understanding of the related environmental elements of spacecraft habitability. They are: texture and pattern, hygiene and mess provisions, dual room usage, gravity, and the interrelation of these elements. These related elements are more subjective than those given in Section 3 since there are no specific values for such an item as texture and pattern. However, these related environmental elements cannot be overlooked when determining an optimum habitat for man.

4.1 TEXTURE AND PATTERN

4.1.1 Requirements. Texture produces the most common yet the least acknowledged sensory experience, that of tactile response. Textures produce such a common source of stimuli to us that we tend to take them for granted. Hence, very little objective data are available on the subject. Textures provide a very valuable means of replacing some of the stimuli which man may be deprived of in the extraterrestrial environment.

Virtually every part of the body is affected by one texture or another throughout the course of a day. The clothes we wear, the surfaces which surround us, every aspect of the environment has one or another quality of surface. Texture is appraised and appreciated almost entirely by touch, even when it is visually presented. With few exceptions it is the memory of tactile experiences that enables us to appreciate texture.

A pattern may be described as a two-dimensional or three-dimensional design put together in a particular arrangement of motifs. Motifs used for patterns may be natural, conventional, abstract, or imaginary.

There is close correlation between pattern and texture; in fact, the difference is almost indiscernible since every pattern creates a texture of some sort. Frequently this texture is only visual, since it does not have a tactile quality. We tend to think of pattern as basically visual and texture as something essentially tactile. The two are thus highly interrelated, and too clear a definition between the two may be misleading.

4.1.2 Definitions.

Texture - Simply stated, texture is the tactile surface quality of an object. It relates to or identifies the tactile reactions of man to the quality of the surface of materials such as smooth, rough, soft, hard, warm, cool, or the many other characteristic variations or combinations possible and available in today's materials technology.

Pattern - Patterns are design motifs of two or three dimensions. These design motifs can be applied to various materials by a number of processes such as printing, silk screening, and painting in a two dimensional form, or by molding, embossing, casting, or forming in a three-dimensional form.

4.1.3 Engineering Data.

4.1.3.1 Texture. We generally think of texture in terms of roughness or smoothness, but our senses also discern between the hardness or softness of an object. Additionally, we anticipate that certain surfaces will be either warm or cool to the touch; we remember what a particular object should feel like. We expect a shaggy rug to be soft and warm, and a metal surface to be smooth, hard, and cold.

Broad definitions of each type of surface texture are given below; these are relative terms, in order to make some distinction possible in the discussion of various textures.

Rough - Absorbs light and makes colors appear darker than they are, due to shadows created. Rough textures are generally considered more rustic, and therefore, less formal. Rougher textures are practical where hard wear is expected and generally can be considered to be humanizing in their effect. These textures broadly fall into the category of more natural type materials - deep wood grains, coarse fabrics or fibers, and pebbled surfaces.

Smooth - A smooth texture gives little or no decorative interest except for its color or pattern. Smooth surfaces tend to be cool-looking and are appropriate in spaces where cleanliness and function are of primary importance.

Very Smooth - The natural result of a very smooth surface is a high reflectance factor; these surfaces should not be used in any area where eyestrain could result. It should be noted that highly reflective surfaces can be used effectively in contrast with roughly textured surfaces to create variable visual interest; these surfaces are particularly good for use on small decorative items.

Soft - Deep pile textures create a feeling of warmth and luxury and are most effective where the body comes into contact with the surface. Soft materials retain temperature and produce an inherent warmth.

Absorption and retention of body heat over prolonged periods should be considered.

Hard - We visually tend to equate smooth surfaces with hard qualities. Also, we generally tend to expect such a surface to be cool. This can be modified with the use of color and roughness to produce the desired warmth.

4.1.3.2 Pattern. The proper use of patterns depends on the principles of good design, but special attention should be given to the effect of overall rhythm and color. Patterns generally have movement, and they should be used in the most effective flow in the interior.

Patterns are primarily used to provide interest, contrast, variety, illusions of surface textures, space, height or length, or for design emphasis. Patterns may also be used for more functional purposes such as directional guides, sports or games. In rooms where function is primary, such as kitchens, baths, and certain kinds of workrooms, patterns can be more daring or amusing as long as color and scale are appropriate. Surfaces or spaces adjoining patterned areas should be planned to harmonize; otherwise, the spaces will not have unity and will not be pleasant.

It is most difficult to define specifics for application of patterns. The use of the properly selected patterns is related to so many variables that specifics are almost impossible to define. Discretion in application is the most important factor, and a sense of pacing of busy areas related to less involved areas is important to build into planning. It will sometimes be possible to incorporate decorative interest into those areas where friction and grip requirements exist, rather than treating these requirements separately.

4.1.4 Surface Effects. All tests to date within confined areas (regardless of volume) have produced a common result. The need for sensory stimuli of a variable nature is extremely important. Particularly necessary are those objects or surfaces which produce a humanizing influence on the environment. Plants, wood grains, and soft carpeted surfaces are indicated as major factors in overcoming normal sensory deprivation.

Texture can create sensory variants within a fixed area. All the senses of man have the characteristic of adaptation to stimuli impinging on them; hearing organs adapt to a fixed noise level, eyes adapt to fixed intensity

levels, etc. Our sensory apparatus responds best to a varying sensory environment, and variation in surface quality provides a simple method of achieving this. Thus, texture and pattern represent very valuable tools in the creation of a habitable environment. Touch is the most personal of all sensory stimuli, and as such is a major aspect of the environment.

Certain effects can be noted for use in application of textures or patterns. A number of these are indicated in Table 4-1. They are general in nature and should be used for basic guidance only.

Table 4-1. Types and Effects of Textures and Patterns

Basic Type	Effects
Large	Tends to make spaces appear smaller than they actually are. Large bold patterns are stimulating and seem to make time go slower. Good for recreation, dining, snack bars, etc.
Small (Directional)	When used on walls, small vertical patterns tend to increase the apparent height of ceilings, while horizontal patterns tend to lower the apparent ceiling height. The small pattern should be used in spaces where neat symmetry and quietness is desirable, such as a bedroom or study.
All-Over (Non-directional)	Tends to camouflage jogs in walls and unify odd-shaped spaces. Should be used in conjunction with solid colors, since other patterns used in the same space would compete for dominance.
Mural or Scenic	Gives illusions of space, such as mountain scenes, countrysides, gardens. Used to carry the eye out and away from enclosing walls. Very restful, used most effectively in small confined spaces. Essentially a deceptive device, and not intended to really fool the observer. Should be used with great discretion.
Copies and Natural Materials	Woods, stones, brick, leather, etc. may be either imitation or natural materials. Textures and patterns of natural materials create feelings of warmth and well-being and are associated with home and earth. Good for studies, lounges, libraries, etc.
Textured Patterns	These patterns have a three-dimensional appearance, such as woven threads or fibers. They are usually found in neutral tones that give variety without adding color or strong pattern. Can be used effectively in work spaces, libraries, offices, etc.
Borders and Stripes	Provides vivid color or accent motif where fully patterned wall would be too strong. Used primarily for accents.

4.1.5 Application. The functional applications of texture (or pattern) are fairly obvious, e.g., providing non-skid surfaces where necessary or providing grip surfaces. Smooth textures should be used in those areas which have cleanliness as a primary consideration, e.g., personal hygiene areas, laboratories, and galleys.

Where smooth surfaces are desirable, their appearance can be easily modified by the application of any pattern to the surface so that cleanliness can easily be accomplished without sacrificing visual effectiveness.

Textures and patterns should be applied with great discretion and in conjunction with all other interior disciplines. Other factors can affect a texture or pattern significantly. For example, light placed at a severe angle to a textured surface will greatly enhance the textural quality, as the shadows created magnify the illusion of the texture. Similarly, placing a dark color in the recesses of a texture or pattern and a lighter shade on the foremost surface achieves a greater illusion of depth.

4.2 HYGIENIC AND MESSING FACILITIES

4.2.1 Requirements. The hygienic* and messing facilities provided on a spacecraft are important not only from the standpoint of crew personal cleanliness, but also because of behavioral and social considerations. A situation where personal hygiene is largely neglected can be tolerable for limited time periods for small crews. Makeshift eating arrangements are acceptable for the same conditions. For the anticipated future mission profiles, however, functionally distinct and more permanent facilities are required.

With larger crews performing a variety of tasks in many different locations in the vehicle, the arrangement of hygiene facilities, the type and number of facilities required, and the dining seat arrangement will vary according to the specific mission profile. General standards have been established by considering those profiles and by analyzing expected usage rates and periods.

Data pertaining to hygienic facilities required for internal body waste elimination, full body cleansing, and various external surface activities concerned with personal hygiene are presented in this section. Use ratios for the various hygienic facilities and design considerations are also included in this section. Classification of spaces into basic occupancy groups has been employed as a means of determining more precisely the numbers, types and locations of hygienic facilities.

Hygienic facilities concerned with general housekeeping, medical, dental, or laboratory functions are specialized areas that are beyond the scope of this section. Also, mess provision data pertaining to types of food preparation equipment, food storage, menus, or refuse disposal are beyond the scope of this section.

4.2.2 Definitions.

Persons - This term refers to both men and women.

Occupancy Group - This term refers to the basic purpose for which a space is to be used. Occupancies are classified into five basic

*Refer to Volume 6, Personal Hygiene, for detail data.

groups: (1) assembly spaces, (2) living spaces, (3) work spaces, (4) food preparation and serving spaces, and (5) service spaces. See Table 4-2 for detailed classification of occupancy groups.

Table 4-2. Occupancy Classification

Occupancy Group	Description of Occupancy
Assembly spaces	Places of worship, auditoriums, theaters, etc., where persons congregate for periods of one hour or more
Living spaces	Sleeping compartments, lounges, studies, libraries, dormitories, recreation rooms
Work spaces	Control rooms, offices, laboratories, shops, computer rooms, communications
Food preparation and serving spaces	Kitchens, galley, snack bars, food storage, dining rooms
Service spaces	Laundry, supply, equipment, power, storage

Maximum Fixtures Per Person - As used in the graphs, maximum fixtures per person refers to a ratio of fixtures to persons that would result in a low to moderate usage of fixtures. There would be little or no waiting time or inconvenience even during peak periods.

Optimum Fixtures Per Person - As used in the graphs, optimum fixtures per person refers to a ratio of fixtures to persons that would result in a moderate to high usage of fixtures. One could expect some waiting and inconvenience during peak periods.

Minimum Fixtures Per Person - As used in the graphs, minimum fixtures per person refers to a ratio of fixtures to persons that would result in a high usage of fixtures with an anticipated moderate to high inconvenience factor, due to waiting for fixture during peak or rush hours. Some waiting or inconvenience might be expected during off-peak hours.

Personal Hygiene Module - A facility or space that contains the following individual personal items: shaver, mirror, hairbrush, comb, nail clipper and file, deodorant, hair dressing, shampoo, soap, first aid, towels, and oral hygiene provisions.

Classification of Occupancy Groups - Table 4-2 defines the occupancy groups.

Toilet - A fixture of receptacle in which a person dan defecate or urinate. The fixture must dispose of or flush away the waste matter.

Urinal - A fixture or receptacle in which a male person can urinate. The fixture must dispose of or flush away the waste matter.

Lavatory - A bowl or basin designed specifically for washing the face or hands.

Dental Lavatory - A small lavatory designed specifically for oral hygiene functions such as brushing teeth.

Shower - A fixture or facility for full-body cleansing under a spray of water or other suitable liquid.

4.2.3 Engineering Data. In establishing the hygienic facilities standards, the usage rates of the facilities were considered. The normal micturation rate is five per man per day at one-minute per event and the normal defecation rate is one per man per day at five minutes per event. These figures indicate the large rate at which facilities possibly could be used.

Usage periods were also considered in establishing the facilities standards. Since twelve to sixteen hours will be spent each day in the living spaces, the facilities in these areas will get the most usage. The daily defecation and three urinations will probably occur in these areas over widely spaced periods throughout the day. Other micturations should occur in work spaces and in other occupancy areas. Hygiene facilities in food preparation and serving spaces or assembly spaces will experience intermittent periods of very heavy use.

The dining area must be capable of seating certain percentages of the total crew at any one time. For small vehicles and minimum crews, this percentage is at or near 100 percent; that is, the complete crew could eat at one time. As vehicle and crew sizes increase, the required seating percentage decreases until, for a crew of 100, the optimum dining seat requirement is 60 seats and the minimum is 40 seats (see Figure 4-8). Consequently, eating periods for larger crews will be staggered in order to minimize the required dining space.

4.2.4 Design Considerations. Personal hygiene can be distinguished between activities concerned with internal waste material elimination, full body cleansing, and various external surface activities. See Table 4-3 for general classification and arrangement.

Table 4-3. Hygiene Requirements

Classifications	Activities	Arrangement
Internal waste elimination	Urine elimination Fecal elimination	Individual privacy required
Full body cleansing	Bathing	Individual privacy highly desired
External surface activities	Washing hands Washing face Hair grooming Shaving	Individual privacy desired but may be acceptably performed in communal spaces.

Separate hygienic facilities should be provided for each different occupancy group when feasible. Toilets, lavatories, and showers should be selected and arranged so the personnel can use them in the shortest time. If a hygienic facility is provided to serve all occupancy groups, maximum effort shall be made to locate it in the vicinity of the living spaces. If overlapping usage of hygienic facilities by different occupancy groups is necessary, then the most stringent occupancy condition must govern the fixture/person ratio. Overlapping periods of maximum usage must also be taken into consideration when designing communal facilities.

The maximum distance from any space to a hygienic facility required for that space must not exceed the distances in feet or levels shown in Table 4-4.

Table 4-4. Maximum Distance to Hygienic Facilities

Mission Duration (months)	Maximum Distance (ft)	Maximum Floor Levels
0 - 3.5	100	2
3.5 - 8.5	75	1
8.5 and up	35	0

Access to wash room facilities shall be provided in a manner to eliminate the need for passing through a toilet area enroute to or from a wash room facility. In the event a communal hygienic facility is essential due to spatial limitations, it is important that all of the crew using a specific facility be of the same peer group if housekeeping is to be divided equally. Therefore, it is recommended that communal hygienic facilities be avoided when possible, but where spatial limitations require their existence, it is essential that privacy partitions be installed isolating the individual waste area. Table 4-5 presents an evaluation of the merits and deficiencies of various concepts of hygienic facility arrangements.

Messing facilities are to be located adjacent to lounge and rest room facilities when possible. In multi-level structures the messing facility shall be near stairwells or elevators. However, maximum effort shall be made to provide messing facilities that permit a variation in the type of food services available for each meal, i.e., cafeteria, self-service, table service.

Table 4-6 lists the requirements for hygiene facilities for the various occupancy groups. This table is to be utilized with "use ratio charts" shown in Figures 4-1 through 4-7. Table 4-7 presents an evaluation of the merits and deficiencies of various mess seating concepts. Figure 4-8 presents recommended maximum, optimum, and minimum seating ratios for dining spaces.

Table 4-5. Evaluation of Various Hygienic Facility Concepts

Concepts	Merits	Deficiencies	Development Status	Applicability & Reliability	Other Factors
Have separate hygienic facilities only within sleep compartments and dormitories; have other hygienic facilities serve several occupancy groups.	Saves in weight, and volume. Makes good use of facilities.	Greater inconvenience for crews. Facility requirements between certain areas may conflict.	Logistics problems require development of suitable arrangement of facilities. No other unique development problems.	Distance restrictions may present problems on multi-level space station/base. Some other separate facilities may be required.	
Locate all hygienic facilities in central communal area to serve all occupancy groups.	Requires minimum facilities, simplifies plumbing.	Lack of privacy and walking distances may make this concept unfeasible.	Development of low-gravity facilities required. No additional development problems.	Possible only on small space stations because of distance and privacy considerations.	Restriction to communal facilities only may be unacceptable both psychologically and socially.
Have separate facilities in each different occupancy group based on expected manpower and requirements in each space.	Most convenient for crew. Optimum privacy.	High cost in volume, weight, complexity.	Specific requirements for each facility would be fixed by actual mission model. No unique development problems.	Most suitable for very long-term missions and very large spacecraft.	Psychological importance of convenience factor significant on long-term mission.

Table 4-6. Hygiene Facilities Requirements

Occupancy Group	Facility Types					
	Toilets	Urinals	Lavatories	Showers	Laundry	Other Facilities
Assembly spaces	See Figure 4-1	See Figure 4-1	See Figure 4-4	Not required	Not required	
Work spaces	See Figure 4-2	See Figure 4-2	See Figure 4-5	Safety showers are to be provided for each 10 persons exposed to excessive heat or irritating materials.	Not required	Provide sanitary napkin dispensing and disposal facilities for female personnel.
Living spaces	See Figure 4-3	See Figure 4-3	See Figure 4-6	See Figure 4-7	Not required	Provide sanitary napkin dispensing and disposal facilities for female personnel.
Kitchen and food preparation spaces	See Figure 4-2	See Figure 4-2	See Figure 4-5	Not required	Not required	Special design criteria to be established for each kitchen or food preparation space.
Service spaces	See Figure 4-2	See Figure 4-2	See Figure 4-5	Not required	Wash and dry facilities - 16 lbs of water per man per day.	

Table 4-7. Evaluation of Various Mess Seating Concepts

Concept	Merits	Deficiencies	Development Status	Applicability & Reliability
2 men seated per table	High accessibility, personalized environment; Conversation easy	Wasted space	No development problems	Applicable to only very small crews or in special areas.
4 men seated per table	Accessible, normal eating environment; Conversation easy	Wasted space, if number of tables is large	No development problems	Optimum for smaller crews
10 men seated per table	Saves space, maximum space utilization	Impersonal environment, less accessibility	No development problems	Necessary for larger crews
Combination of small and large tables	Diners given preference, maximum utilization of space in "odd" areas. Provides variety of dining environments	Arrangement must be worked out to minimize wasted space. May result in status seeking	No development problems	May be necessary on large vehicles or long-term missions because of social and psychological requirements

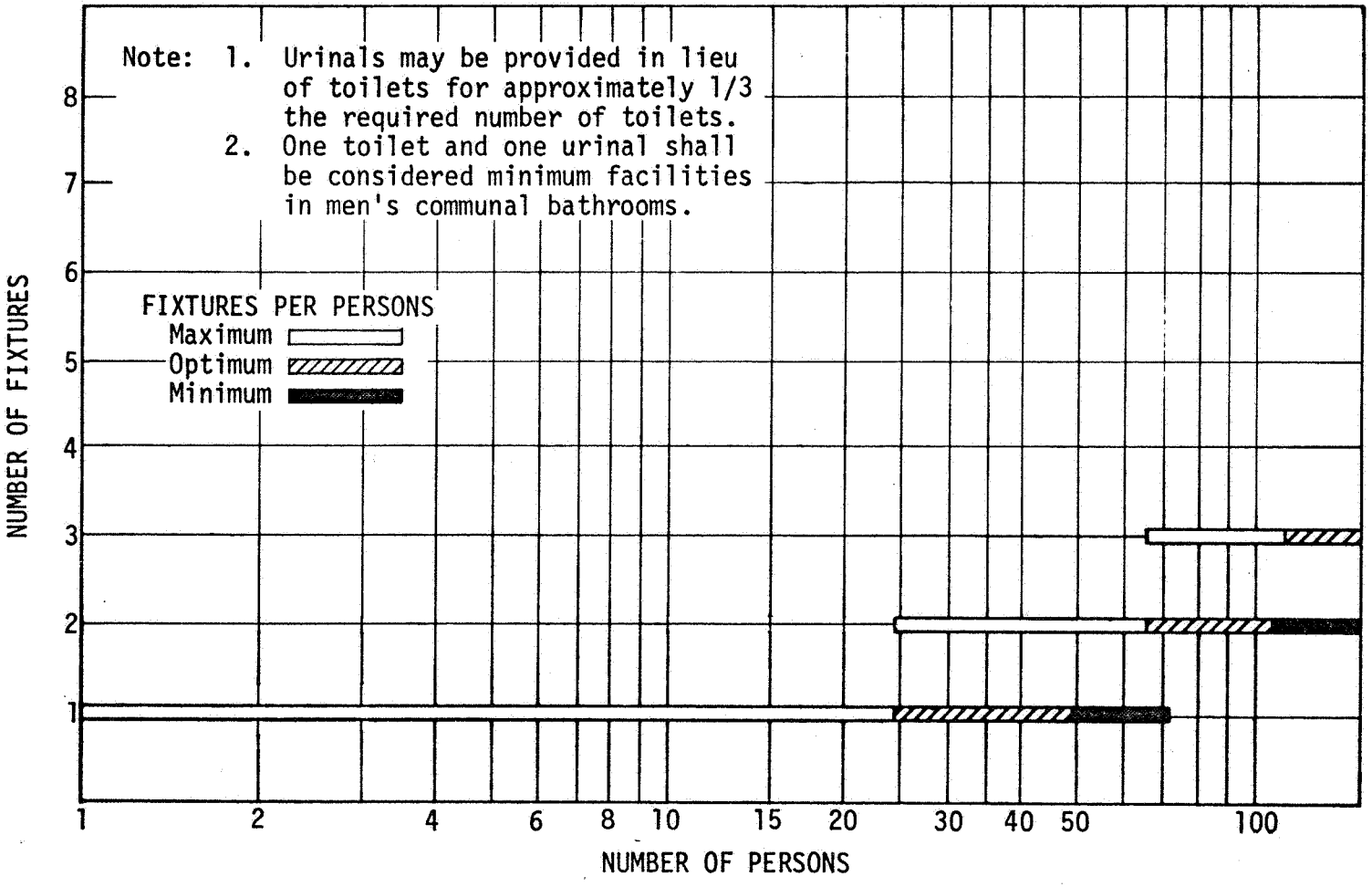


Figure 4-1. Toilet Use Ratio Chart #1

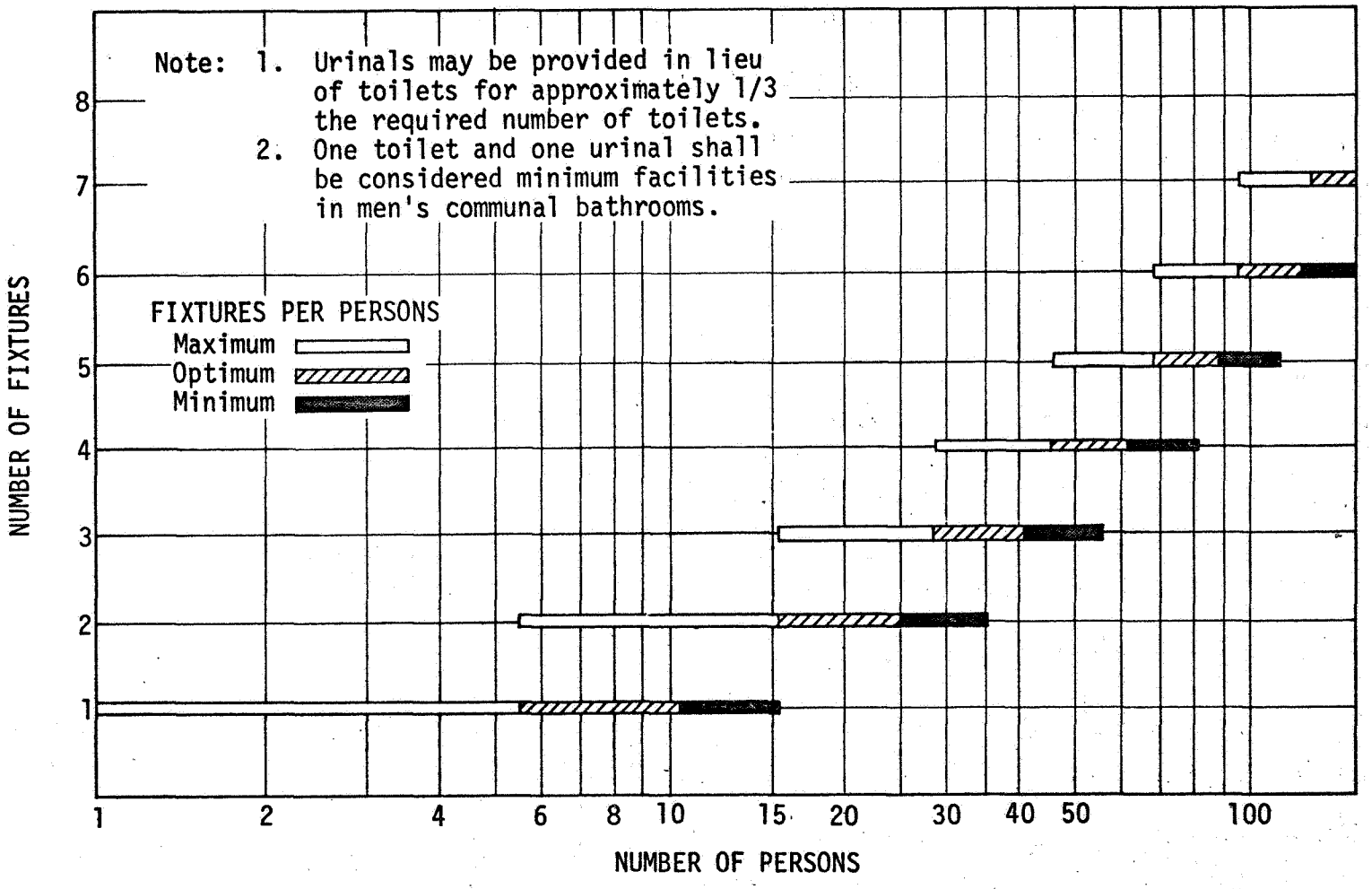


Figure 4-2. Toilet Use Ratio Chart #2

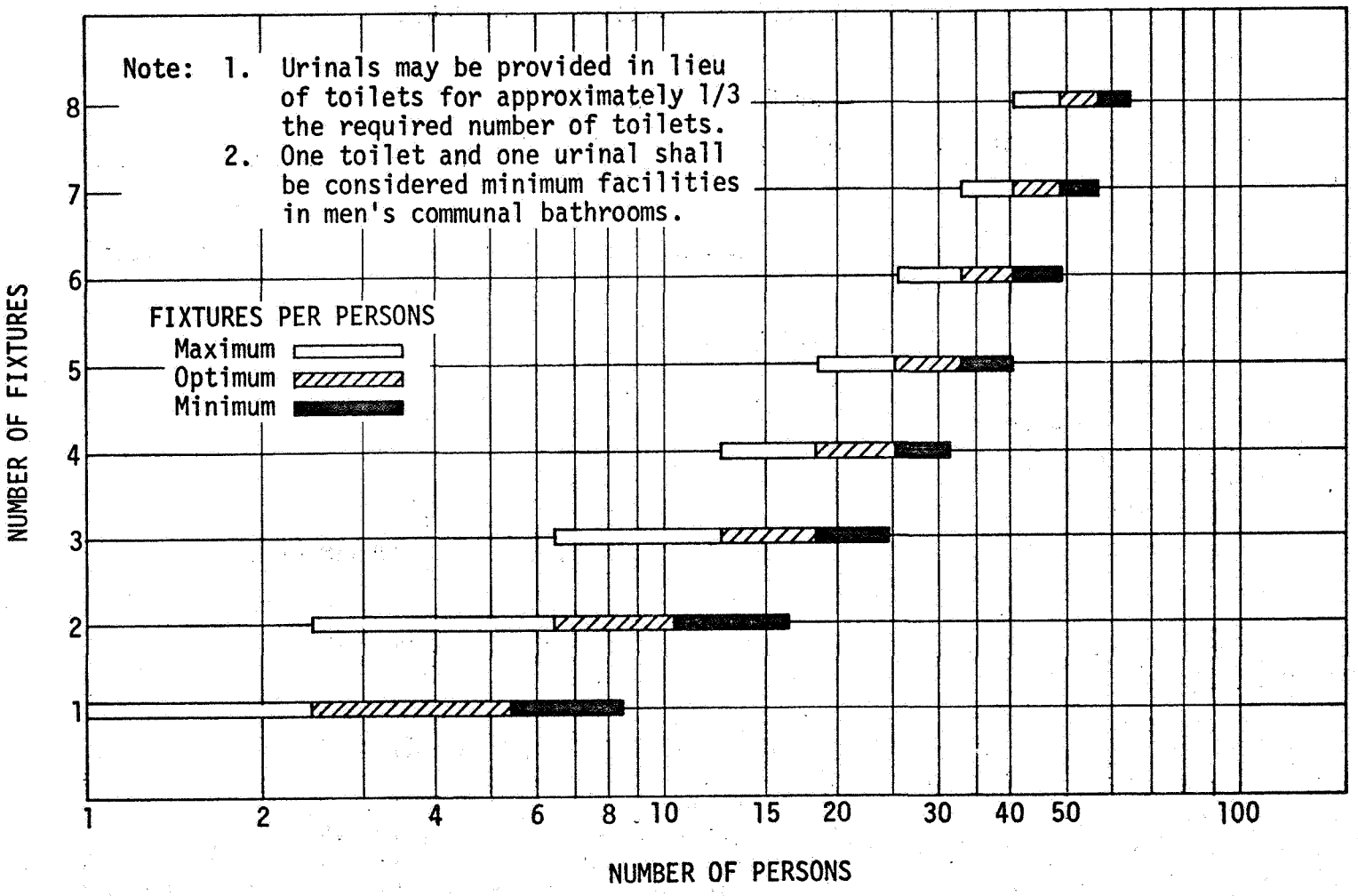


Figure 4-3. Toilet Use Ratio Chart #3

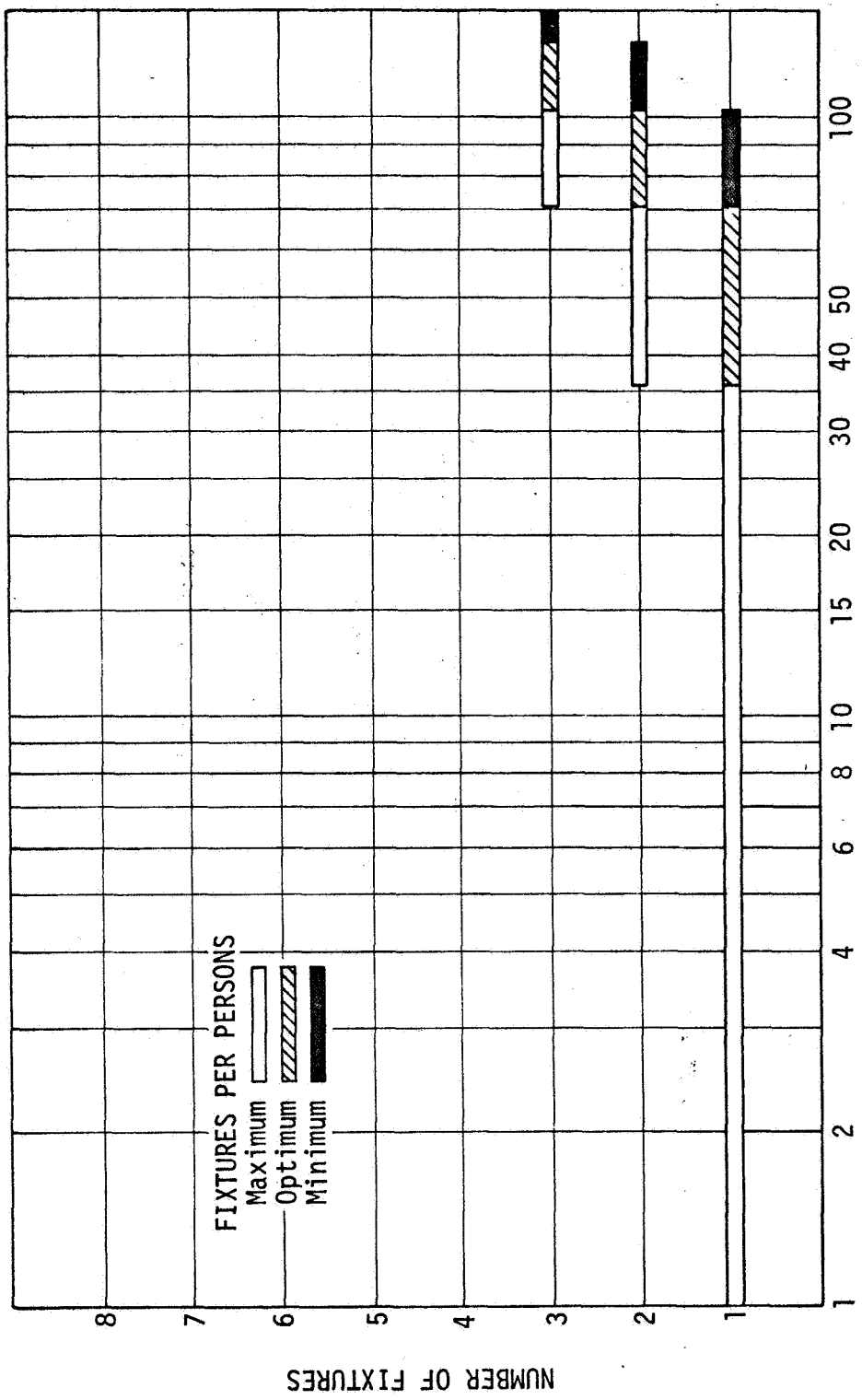


Figure 4-4. Lavatory Use Ratio Chart #1

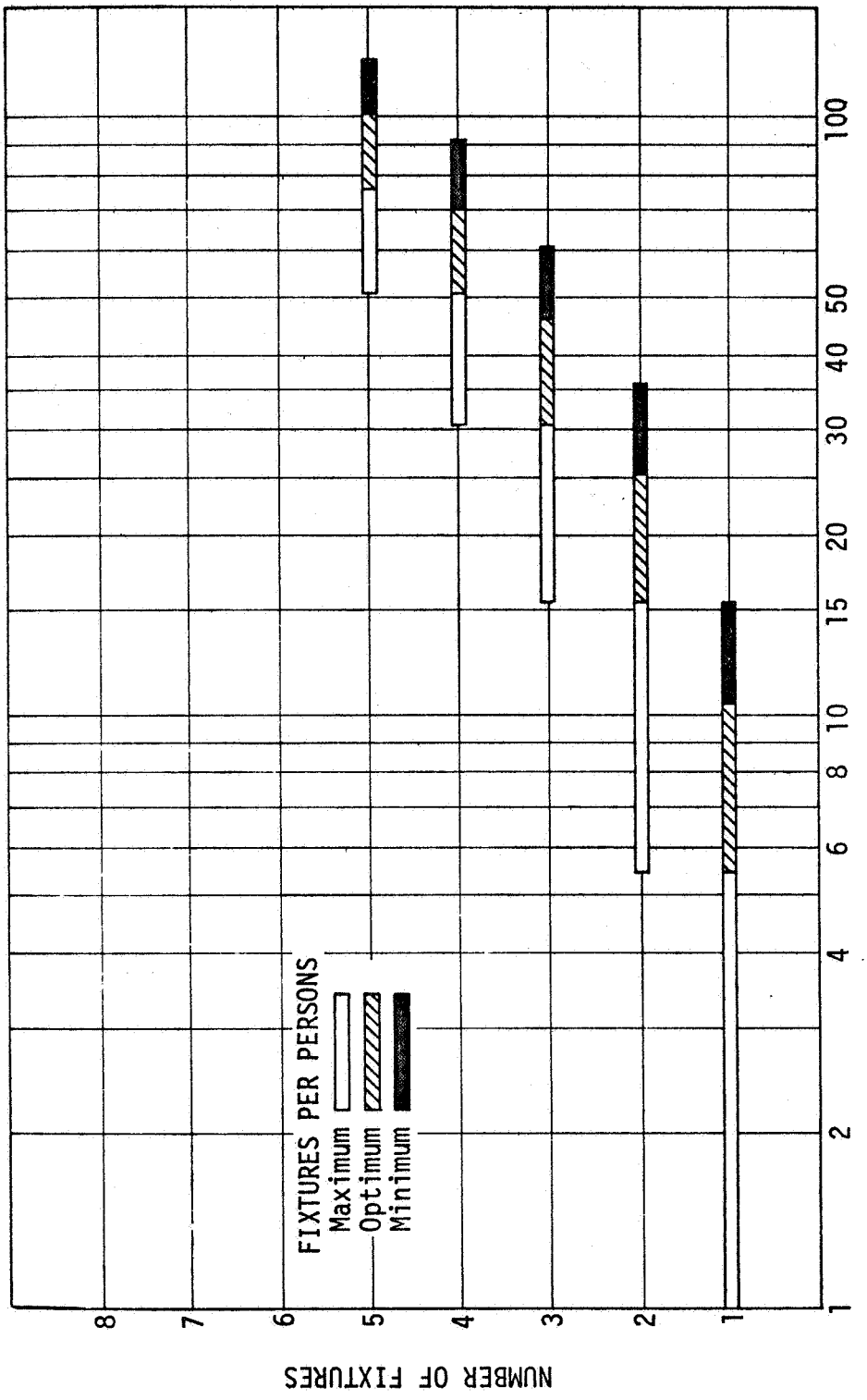


Figure 4-5. Lavatory Use Ratio Chart #2

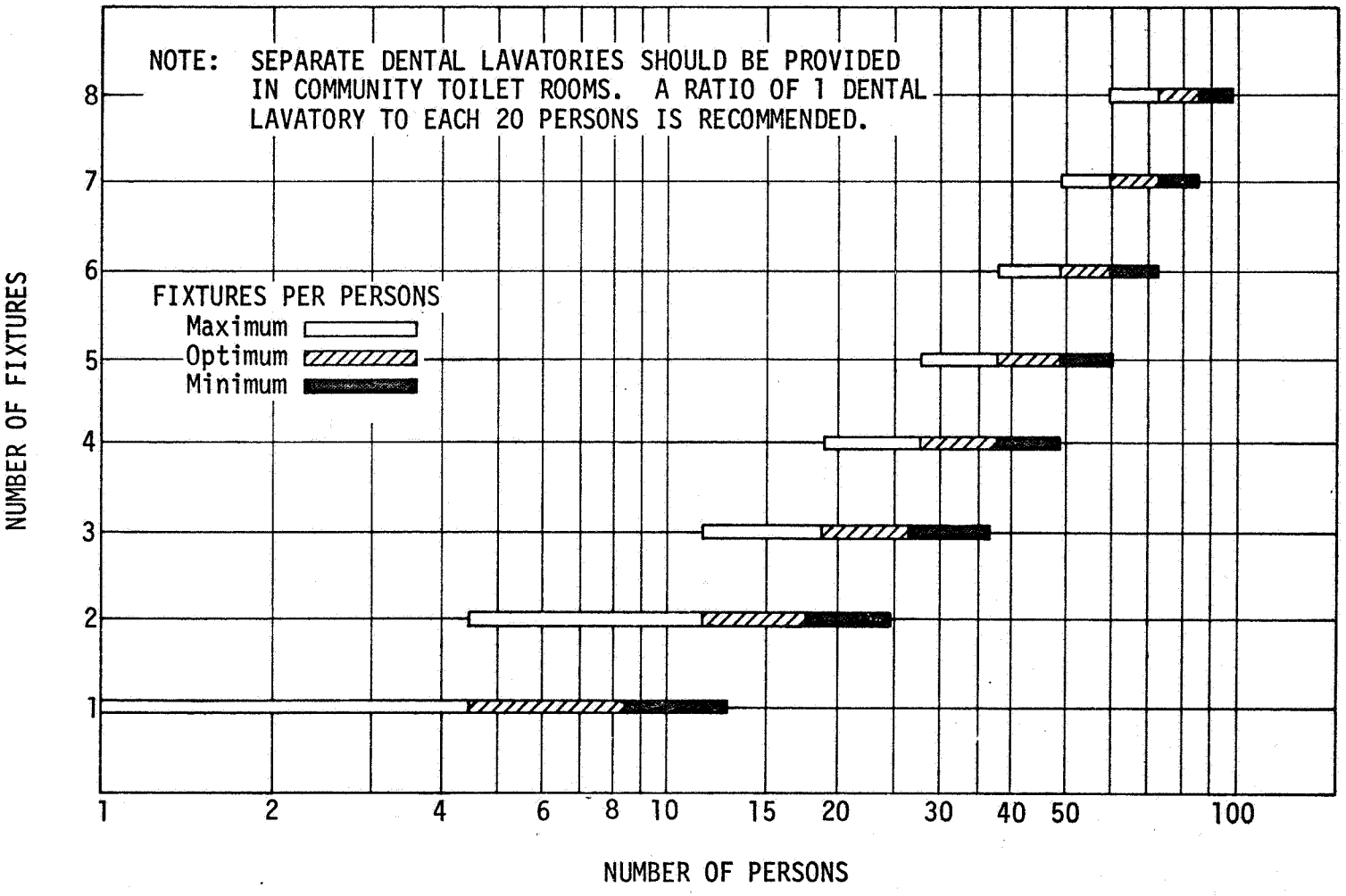


Figure 4-6. Lavatory Use Ratio Chart #3

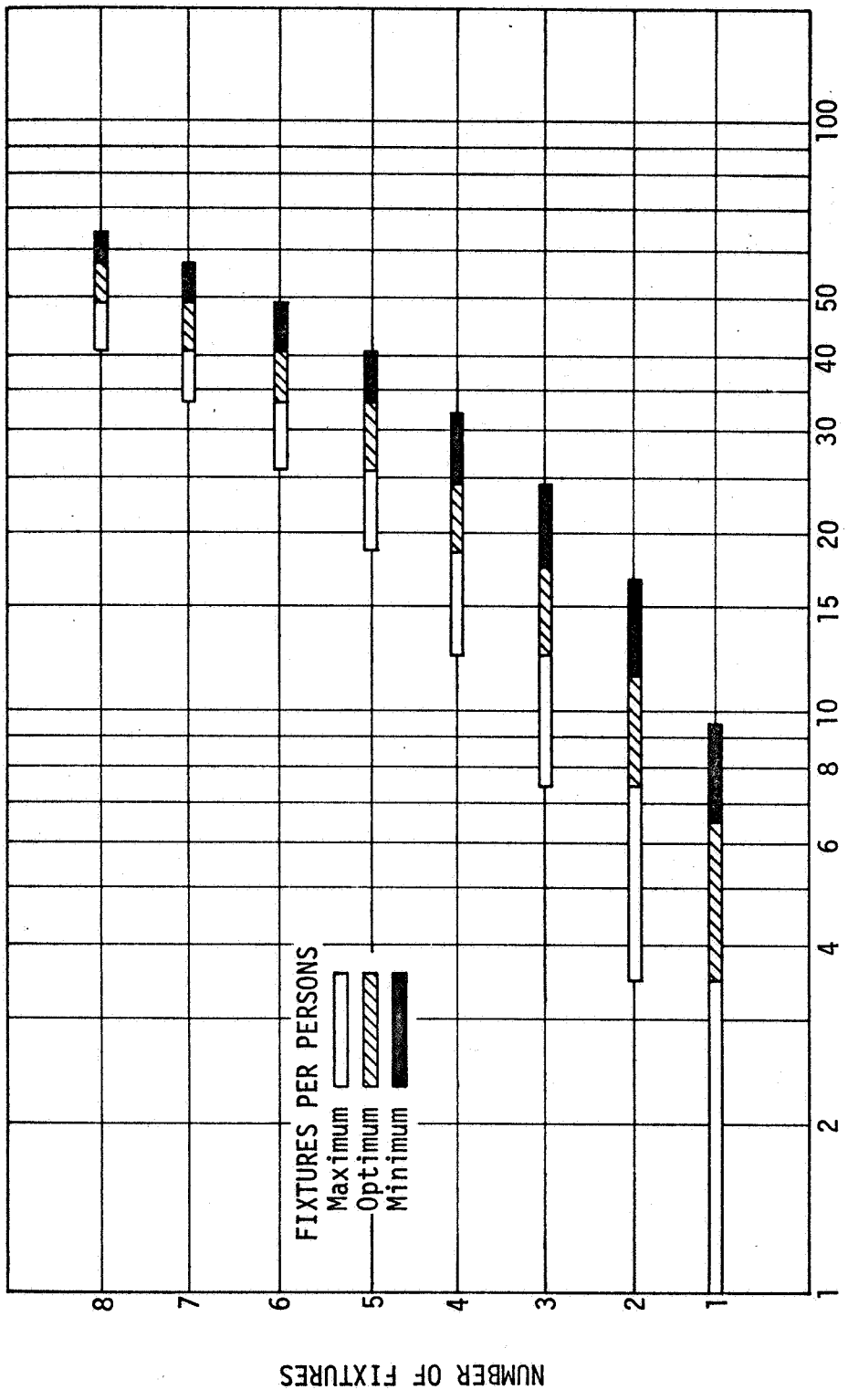


Figure 4-7. Shower Use Ratio Chart

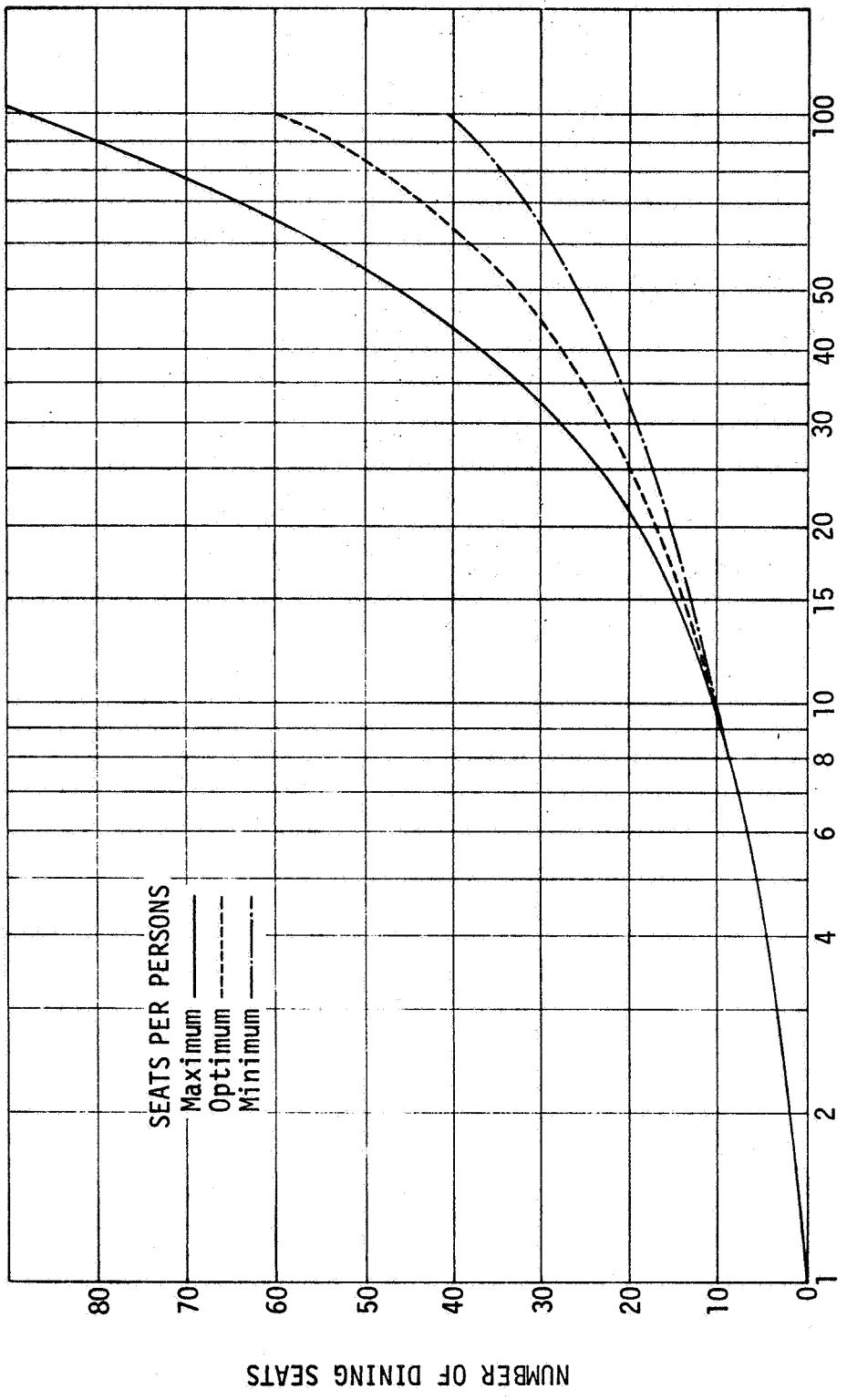


Figure 4-8. Seating Use Ratio Chart

4.2.5 Design Example.

Requirement: Provide the maximum number of toilets required in a sleeping compartment that contains four men on a mission scheduled for six months duration.

Solution:

Step 1: Using Table 4-2, determine in which occupancy group a sleeping compartment is classified. Solution: Living Spaces.

Step 2: Enter Table 4-6 at occupancy group - "Living Spaces". Proceed to column under toilets. Read: "See Figure 4-3."

Step 3: From Figure 4-3, enter number of persons at 4 and read vertically until in "maximum fixtures per person" area. Read across horizontally to "number of fixtures". Answer: 2.

Step 4: Determine maximum distance from living area to toilet from Table 4-4. At 6 months read 75 feet maximum distance and one floor maximum.

From the data, the maximum number of toilets to be provided would be 2. These toilets must be located not more than one level away and must not exceed a distance of 75 feet from the sleeping compartments.

4.3 DUAL ROOM USAGE

4.3.1 Engineering Data. The term dual room usage refers to the practice of providing facilities for two or more activities in one compartment. Specifically, dual room usage refers to the combination of two or more active activities such as dining and lounging rather than combinations involving passive activities such as storage. The success of the mating of activities depends on the degree to which the activities are compatible, that is, how capable they are of functioning together harmoniously.

In order to establish parametric guidelines for compartmentalization levels* for specialized and combined activity compartments for extraterrestrial habitats, it is necessary to rely entirely on extrapolated data from environmental simulation, historical precedence, and common sense.

An advantage of dual room usage is that spatial efficiency is realized and larger open areas become practical when activities are combined. A disadvantage of dual room usage is that compartmentalization level reduction results in a lower level of sensory stimulation along with scheduling and environmental, e.g., noise level, compromises.

Dual room usage is used as a means of making the most of limited space in all types of habitats, from efficiency apartments to submarines. An extreme example of this practice is seen in the Gemini space vehicles in which one compartment served as the dining room, bedroom, control room and bathroom for two men for periods of confinement of up to 14 days. Although this vehicle proved to be adequate for the mission and individuals it was designed to support, there is little doubt that it represented the extreme lower limits of habitability even though the crew was very highly motivated and trained.

As a general rule, a significant increase in crew size results in a reduction in the effective level of dual room usage, and therefore, an increased level of compartmentalization. The need for the increased specialization

*Compartmentalization levels refers to the number of compartment types required to house the various habitat activities. Separate compartments for dining and bathroom facilities represent two compartment types. Two separate bathrooms represent one compartment type. A combined activity compartment such as the theater/lounge/dining room represents one compartment type.

is attributed to both mechanical system and personnel needs.

In the case of the mechanical systems, as crew size is increased, there is an attendant increase in the physical size of the station or habitat to the point that it is structurally advantageous to subdivide the total volume into a number of compartments. Additionally, an increase in equipment size and degree of specialization (e.g. photography and repair facility) is to be expected with an increase in crew size and specialization level to the point that physical separation of activities is desirable.

In the area of personnel needs, an increase in crew size will result in additional conflicting activity schedules, an increase in personal stress created by sheer numbers, and an increased level of task specialization, all of which may be alleviated by an increased level of compartmentalization in public, private and work areas.

The effect of mission duration on compartment specialization is debatable, depending on the degree of change and specific mission lengths considered. Generally speaking, it is known that the complaint of sameness or monotony in the environment has been common to practically all experimental and operational isolated missions as a result of the low level and non-changing nature of the sensory stimuli.

While insufficient data exist to develop accurate compartmentalization/mission duration relationship guidelines, it is probable that a relationship does exist for significant increases in mission duration, especially for missions from 0 to 60 days. As a general rule, because an increased level of compartmentalization will result in an increased level of visual stimuli and change, a significant increase in mission duration must be accompanied by a reduction in the level of dual room usage. The recommendations presented herein should be used as preliminary study guidelines only.

4.3.2 Degree of Compatibility. Certain points on which activities are compared have a greater influence on compatibility than others. An example of functionally incompatible activites would be a dining room and an activity that required that the temperature be held at 87 ($\pm$1)°F and the humidity be kept at 85-90 percent.

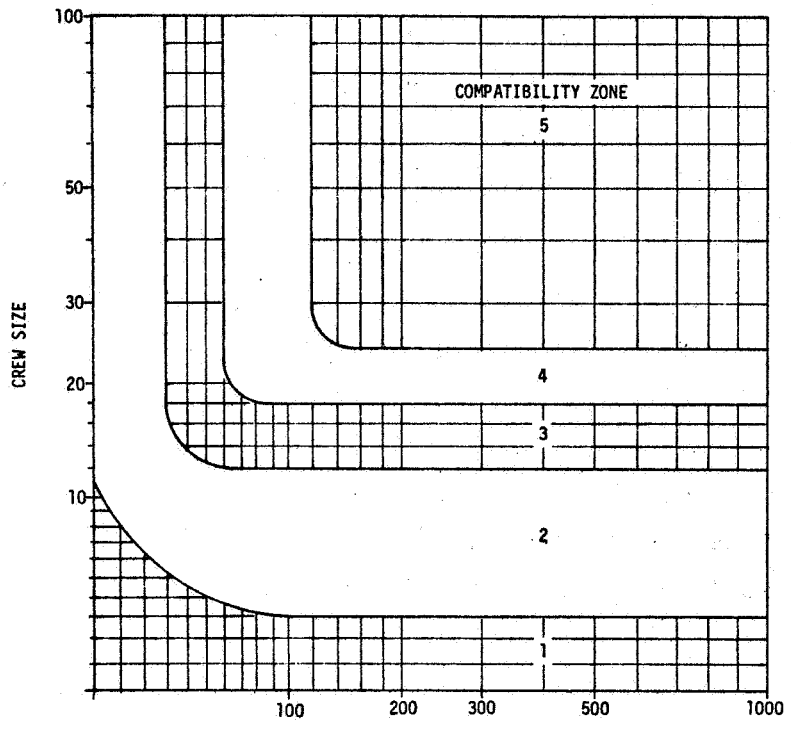
An example of an activity-imposed requirement of a lesser nature is that of material limitations. For example, if a lounge area doubles as a distribution area for supplies during periods of resupply, high standards of material toughness would be imposed on the lounge fixtures exposed to the distribution activities. While these increased standards would decrease the choice of available materials, the area could still support lounging activities, if only a little less graciously.

4.3.3 Efficiency of Combination. The spatial efficiency realized in combining activities varies considerably depending on the nature of the activities involved in terms of layout and associated equipment or function. The dining room and theater combination is an example of optimum efficiency achieved by combining two activities; the space savings realized can be as high as 50 percent since the furniture in both areas is moveable and the schedules of usage do not overlap. The supply room and shop, on the other hand, represent an inefficient combination of activites since both activities contain fixed, incompatible equipment, and the schedules of usage overlap.

4.3.4 Activity Combination Effects. As a general rule, as the number of activities being combined increase and types of activities combined become more diversified, the stresses associated with trying to accomplish a task in this environment will increase.

4.3.5 Application. A system has been developed by which compartmentalization levels may be approximated on the basis of the mission duration and crew size. To utilize the system proceed as follows:

- Step 1 - By referring to Figure 4-9, a mission compatibility rating figure can be determined for a specific mission. Five compatibility rating zones are defined, with the lower rating (1) representing a parametric area in which a high level of dual room usage and corresponding lower level of compartmentilization is practical. The high end of the scale (5) defines a parametric zone which requires a high level of compartmentilization. Missions with large crews and/or very long mission durations fall in this zone.
- Step 2 - Using the compatibility rating found in step 1, select the appropriate list of dual room usage combinations from the following pages.



Compatibility Zone Rating:
1 = Most Effective
5 = Least Effective

Figure 4-9. Compatibility Rating As a Function of Crew Size

Compatibility Level 1*

Personal Quarters	Communications
Study	Control
Locker Room	Computer
Library	Storage
Lounge	Supply
Conference	
Briefing	Equipment
Chapel	Shop
Theater	Maintenance
Dining Room	
Gym	Office
	Laboratory
Passageway	Photographic Support

*Recreation will be supported by a number of activity centers (dining, lounge, gym) and is not considered to be an independent area in these listings.

| Galley
| Snack Bar

| Dispensary
| Barbershop
| Bathroom
| Laundry

| Animal Housing
| Agricultural Study Area

| Dock
| Air Locks

| Power

Compatibility Level 2

| Personal Quarters
| Study
| Locker Room

| Library
| Lounge
| Conference Room
| Briefing Room
| Chapel
| Theater
| Dining Room

| Passageway

| Gym

| Bathroom

| Galley
| Snack Bar

| Laundry

| Dispensary
| Barbershop

| Communications
| Control
| Computer

| Storage
| Supply

| Equipment
| Shop
| Maintenance

| Office
| Laboratory
| Photographic Support

| Animal Housing

| Agricultural Study Area

| Dock
| Air Locks

| Power

Compatibility Level 3

| Personal Quarters
| Study
| Locker Room

| Library
| Lounge

| Conference Room
| Briefing Room
| Chapel
| Theater
| Dining Room

| Communications
| Control
| Computer

| Storage
| Supply

| Equipment
| Shop
| Maintenance

| Office

| Passageway

| Gym

| Bathroom

| Galley
| Snack Bar

| Laundry

| Dispensary
| Barbershop

Compatibility Level 4

| Personal Quarters
| Study

| Library
| Lounge

| Conference Room
| Briefing Room
| Chapel
| Theater
| Dining Room

| Gym

| Locker Room

| Passageway

| Bathroom

| Galley

| Snack Bar

| Laundry

| Dispensary

| Barbershop

Compatibility Level 5

| Personal Quarters
| Study

| Laboratory
| Photographic Support

| Animal Housing

| Agricultural Study Area

| Dock
| Air Locks

| Power

| Communications
| Control
| Computer

| Communications
| Control
| Computer

| Storage
| Supply

| Equipment
| Shop
| Maintenance

| Office

| Laboratory

| Photographic Support

| Animal Housing

| Agricultural Study Area

| Dock

| Air Locks

| Storage

| Supply

- Library
- Lounge
- Conference Room
  Briefing Room
  Chapel
- Theater
  Dining Room
- Gym
- Locker Room
- Passageway
- Bathroom
- Galley
  Snack Bar
- Laundry
- Dispensary
- Barbershop
- Communications
  Control
- Computer
- Equipment
- Shop
  Maintenance
- Office
- Laboratory
- Photographic Support
- Animal Housing
- Agricultural Study Area
- Dock
- Air Locks
- Power

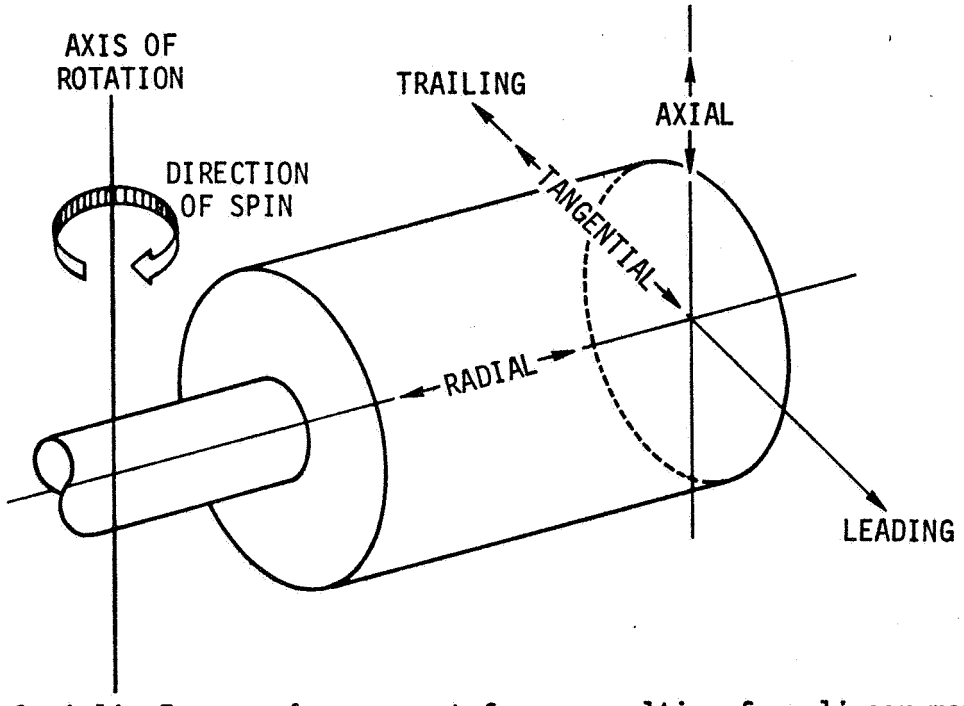
4.4 GRAVITY

4.4.1 Requirements. Gravity, or the lack of it, will have a definite influence on spacecraft habitability. For manned space systems, two gravitation modes of operation are possible: weightlessness and artificially-induced gravity. Weightlessness is the natural state during space travel; artificial gravity requires rotation of the spacecraft about a spin-axis during spaceflight. This section will not establish a requirement for either mode, rather it will state general design details for each.

4.4.2 Definitions.

Artificial Gravity - Apparent weight produced by centripetal forces generated by a rotating spacecraft.

Axes in Artificial Gravity - In the interest of clarity, the directions in which movements are made and external forces are applied will be indicated as axial, radial, or tangential with respect to the rotating spacecraft, as shown in the figure below. Tangential movements and forces may further be described as operating toward the leading edge or the trailing edge of the spacecraft. Thus, a crewman climbing a ladder is translating radially, while a crewman walking in the same direction the spacecraft is rotating is moving tangentially (toward the leading edge).



Coriolis Force - An apparent force resulting from linear movement with a rotating system.

Cross-Coupled Angular Acceleration - Angular acceleration produced by angular movement within a rotating system. Also known as gyro-

scopic precession. When, within a rotating spacecraft, an angular motion occurs about any axis not parallel to the axis of rotation, a torque is applied to the moving object about an axis perpendicular to the axes of motion of the spacecraft and the object.

4.4.3 Engineering Data.

4.4.3.1 Zero Gravity. Past space missions have been of relatively short duration and have not produced any major problems due to protracted weightlessness. There exists a definite possibility that the effects will become more pronounced with longer missions. Whether man experiences a time limitation on his ability to inhabit a weightless environment will depend on whether the deterioration is progressive, or reaches an acceptable asymptotic level with increasing exposure, and on the effectiveness of proposed countermeasures.

4.4.3.2 Artificial Gravity. While artificial gravity induced by spacecraft rotation has the greatest apparent validity as a procedure for preventing possible deconditioning due to protracted weightlessness, it unfortunately involves a number of undesirable phenomena. Because of the unusual forces operating in such an environment (see Figure 4-10), crewmen may anticipate a considerable degree of locomotor difficulty, spatial disorientation, and perhaps motion sickness. The degree to which these adverse effects will be experienced varies with the radius, angular velocity, and gravity level. In general, the degree of performance degradation which will occur is not known, since the conditions encountered in a rotating space station cannot be adequately simulated in a one-g environment.

The static effects of artificial gravity are not very serious, involving only a simple, constant visual-proprioceptive conflict regarding the vertical-horizontal frame of reference. During movement, however, and particularly radial or tangential translation and angular head movements, a number of serious abnormal mechanical and perceptual phenomena will occur. These phenomena may reasonably be expected to result in locomotor difficulty, illusions of spatial perception, motion sickness, and generally degraded performance. The degree to which these factors influence mission success will vary with: (1) the magnitudes of the phenomena, primarily a function of angular velocity, (2) the degree to which adaptation occurs, and (3) the degree to which appropriate equipment design and mission constraints are employed.

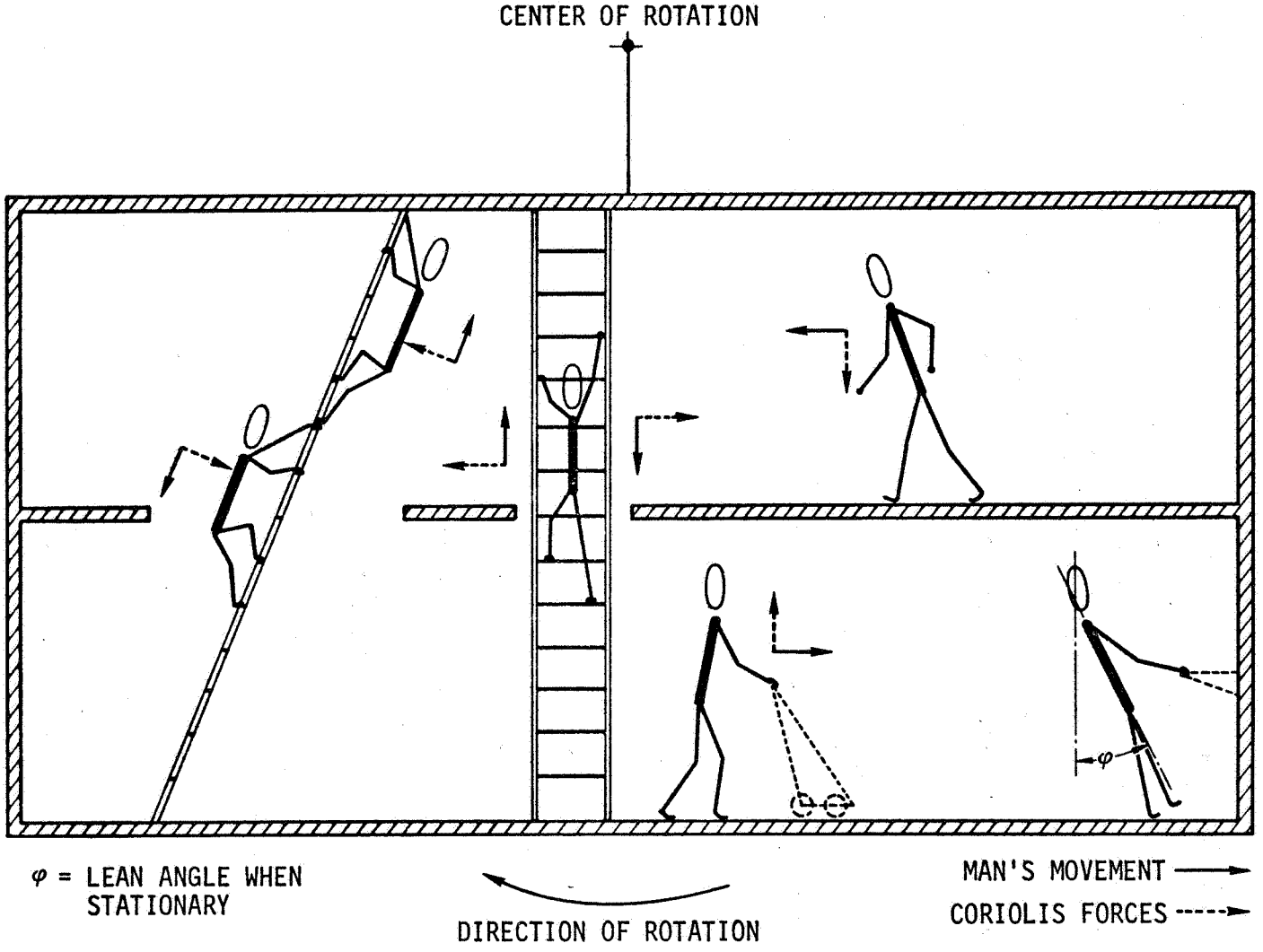


Figure 4-10. Forces in Artificial Gravity

4.5 INTERRELATION OF ENVIRONMENTAL ELEMENTS

4.5.1 Introduction. The assessment of habitability is complicated not only by the large number of possible interrelationships among habitability requirements, but also by the interrelation of habitability requirements and individual differences. That is, habitability is a relative as well as a global concept; optimum habitability for one person may not be optimum habitability for another person.

An example of the problem of individual differences in habitability concerns the use of color in living areas. Generally speaking, most people prefer either warm or cool colors. Personal preference depends on such factors as the individual's familiarity with certain colors and color schemes and the emotional connotations, either conscious or subconscious, that they may have for him. It is generally assumed that emotionally responsive persons will react freely to color, inhibited individuals will feel uneasy with an actively colored environment, and restricted or detached types may be unaffected.

The problem of interrelationships is crucial to the overall problem of habitability. Some of the interrelationships are possible to express in quantitative or qualitative terms; others are impossible to express either quantitatively or qualitatively. The major interacting influences on temperature, illumination and acoustics are presented in the appropriate sections of this volume. However, certain interrelationships stand somewhat alone and are difficult to place in other sections. The major conclusions concerning these are presented in the following engineering data.

4.5.2 Engineering Data.

4.5.2.1 Interrelationships of Interiors. Interrelationships among colors, illumination, shade, and the subjective impressions of time, size, weight and volume are given in Tables 4-8 through 4-12.

Table 4-8. Color Effects on Perceptions of Time, Size, Weight and Volume

Color	Perception of Time	Size	Weight	Volume*
Warm red yellow pink ivory cream peach lemon coral rose wine	Time is over-estimated; use warm colors for areas where time in apparent "slow motion" might be more pleasurable (eating, recreation).	Things seem longer and bigger	Weights seem heavier	Decreases apparent size of rooms
Cool green violet blue bluish-green turquoise lilac lime jade aqua	Time is under-estimated; use cool colors for areas where routine or monotonous tasks are performed.	Things seem shorter and smaller	Weights seem lighter (Use on boxes & containers which must be carried about.)	Increases apparent size of rooms

*The conditions of brightness, color saturation, and level of illumination required to either enlarge or close-in a living area are presented in Table 4-9.

Table 4-9. Brightness, Color Saturation, and Illumination Level Effects on Perception of Volume

Volume (roominess)	Brightness*	Color Saturation	Illumination Level
Enlarge**	Areas will be enlarged by lightness and small paper patterns. (Use to alleviate feelings of oppression or "closed-in".)	Pale or desaturated colors "recede". In situations where equipment projects into a room and tends to make it appear smaller than it actually is, paint the projections the same color as the ceiling or wall-a very light shade-to make them appear to recede into ceiling or wall.	High
Close-in	Areas will be closed-in by darkness and large paper patterns.	Dark or saturated hues "protrude".	Low

*Brightness is a function of reflectance. Tables 4-10 and 4-11 give reflectance factors for typical paint, paper, and wood finishes and Federal Color Standards. Table 4-12 presents the Illuminating Engineering Society's recommendations for reflectance ranges of interior surfaces.

**In establishing space relationships in interiors, there is a natural sequence of perspective where white, black, pure hues, and deep shades will appear near the eye. In what is called aerial perspectives, as colors shift or fall back into the distance, that which is dark increases in value; that which is light softens in value, and all colors eventually fade into medium gray. Color schemes can be planned to feature this phenomenon by using strong contrasts for near elements and grayish or weak contrast for far elements.

Table 4-10. Reflectance Factors for Federal Color Standards (No. 595)

Color	Federal Color Number	Reflectance Percent
Light ivory	13711	75
Soft yellow	13695	72
Peach	12648	64
Sun tan	13613	60
Light green	14516	55
Highlight buff	13578	55
Brilliant yellow	13538	55
Light blue	15526	50
Pearl grey	16492	46
Light Navy gray	16251	29
Bright green	14260	26
Medium green	14277	25
Vivid orange	12246	23
Medium tan	10219	21
Terra cotta	10233	20
Clear blue	15177	19
Spruce green	14159	15
International orange	12197	15
Radiation purple	17142	15
Med. Navy gray	16187	14
Deep green	14158	14
Fire red	11105	7
Deep Navy gray	16087	7
Passive green	14077	7
Passive maroon	10075	7
Marine Corps green	14052	4

Table 4-11. General Reflectance Factors of Paint, Paper, and Wood

Color	Percent of Reflected Light	Color	Percent of Reflected Light
White	85		
Light		Dark	
Cream	75	Gray	30
Gray	75	Red	13
Yellow	75	Brown	10
Buff	70	Blue	8
Green	65	Green	7
Blue	55		
Medium		Wood Finish	
Yellow	65	Maple	42
Buff	63	Satinwood	34
Gray	55	English Oak	17
Green	52	Walnut	16
Blue	35	Mahogany	12

Table 4-12. Reflectance Range for Interior Surfaces

Ceilings	60 to 85 percent (white or pale tint)*
Walls	35 to 60 percent**
Window or glass wall	Fabric treatment: Wide expanse or backgrounds = 45 to 85 percent Limited areas of decorative design on light background or side draperies = 15 to 45 percent
Floors	15 to 35 percent (25 to 35 percent preferred)*** (Values of high end of range recommended for use in rooms where lighting efficiency is a major consideration: kitchen, bathrooms, utility rooms)

* 70 percent or more is required for effective performance of indirect lighting methods.

** Appreciably higher than 50 percent creates brightness problems when portable luminaires are placed near walls and when extensive wall lighting methods are used. According to paint manufacturers, the public prefers 45 percent.

*** Middle to high values preferred because of their predominance within the 60-degree cone of vision when performing many visual activities.

4.5.2.2 Interrelationships in Living Areas. Interrelationships among colors, temperature, sound, and overall subjective impression in living areas are presented in Table 4-13.

Table 4-13. Living Area Interrelationships

Color	Sound	Temperature	Subjective Impression in Living Area
Warm red yellow lemon pink ivory cream peach coral rose wine	Noise induces a hazier perception of warm colors. Brightness, loudness, stimulation of senses in general are associated with the most active effect of warm colors.	Warmness Use to soften up chilly or vaulty spaces.	Centrifugal action - with high levels of illumination, warm and luminous colors, the person tends to direct attention outward. There is an increase in alertness, outward orientation, and activation. Such an environment is conducive to muscular effort, action, and cheerfulness.
Cool green blue violet lilac bluish-green turquoise lime jade aqua	Noise increases sensitivity for cool colors. Dimness, quietness and sedation of the senses in general are associated with the most active effect of cool colors.	Coolness Use where working conditions expose person to warm temperatures.	Centripetal action - with softer surroundings, color hues, and lower levels of illumination, there is less distraction and a person's ability to concentrate on difficult visual and mental tasks is enhanced. Good inward orientation is furthered.

4.5.2.3 Interrelationships of Colors, Odors and Taste. The colors pink, lavender, pale yellow, and green have pleasant associations with odors. The tints of coral, peach, soft yellow, and light green, and the richer colors of vermillion, flamingo, pumpkin, and turquoise have pleasant associations with taste. The use of any of these colors in food preparation areas has been shown to facilitate appetite appeal.

4.5.2.4 Interrelations Between Color and Type of Illumination. In the field of interior color, the expression true color has no meaning. Light modifies colors in an almost infinite number of ways. The effects of artificial illuminants on the perception of color is of particular interest in establishing habitability illumination requirements; therefore, the effects of white fluorescent lamps and mercury and filament lamps on the perception of colors are given in Tables 4-14 and 4-15.

A related problem concerns the normal appearance of object colors; for example, the normal appearance of human flesh. The normal appearance for object colors will require different tints in a light source, depending on the degree of illumination intensity. Colors of objects and surfaces will have a pleasing and natural appearance only if the color tint of the light source is warm (pink, orange) at low levels of intensity and whiter and cooler at high levels of intensity. Figure 4-11 demonstrates the region of natural appearance for object colors in relation to the tint of light source; the level of illumination lies within the crosshatched area.

Note that for good and flattering human appearance, warm light is required at low levels of illumination and whiter (cooler) light is required at higher level of illumination.

4.5.2.5 Interrelationship of Volume and Ventilation. Often the production of body odors in an enclosed space requires ventilation. The data plotted in Figure 4-12 are the minimum odor-free requirements to remove objectionable body odors under laboratory conditions for sedentary adults and for adults engaged in manual tasks.

Table 4-14. Color Effects of White Fluorescent Lamps

	Cool White	Deluxe* Cool White	Warm** White	Deluxe** Warm White	Daylight	White	Soft White Natural
Lamp appearance; effect on neutral surfaces.	White	White	Yellowish white	Yellowish white	Bluish white	Pale yellowish	Pinkish white
Effect on "atmosphere"	Neutral to moderately cool	Neutral to moderately cool	Warm	Warm	Very cool	Moderately warm	Warm Pinkish
Colors strengthened	Orange Yellow Blue	All nearly equal	Orange Yellow	Red Orange Yellow Green	Green Blue	Orange Yellow	Red Orange
Colors grayed	Red	None appreciably	Red Green Blue	Blue	Red Orange	Red Green Blue	Green Blue
Effect on complexions	Pale pink	Most natural	Sallow	Ruddy	Grayed	Pale	Ruddy pink
Remarks	Blends with natural daylight.	Best overall color rendition; simulates natural daylight.	Blends with incandescent light.	Excellent color rendition; simulates incandescent light.	Usually replaceable with CW.	Usually replaceable with CW or WW.	Usually replaceable with CWX or WWX.

*Greater preference at higher levels

**Greater preference at lower levels

Table 4-15. Color Effects of Mercury and Filament Lamps

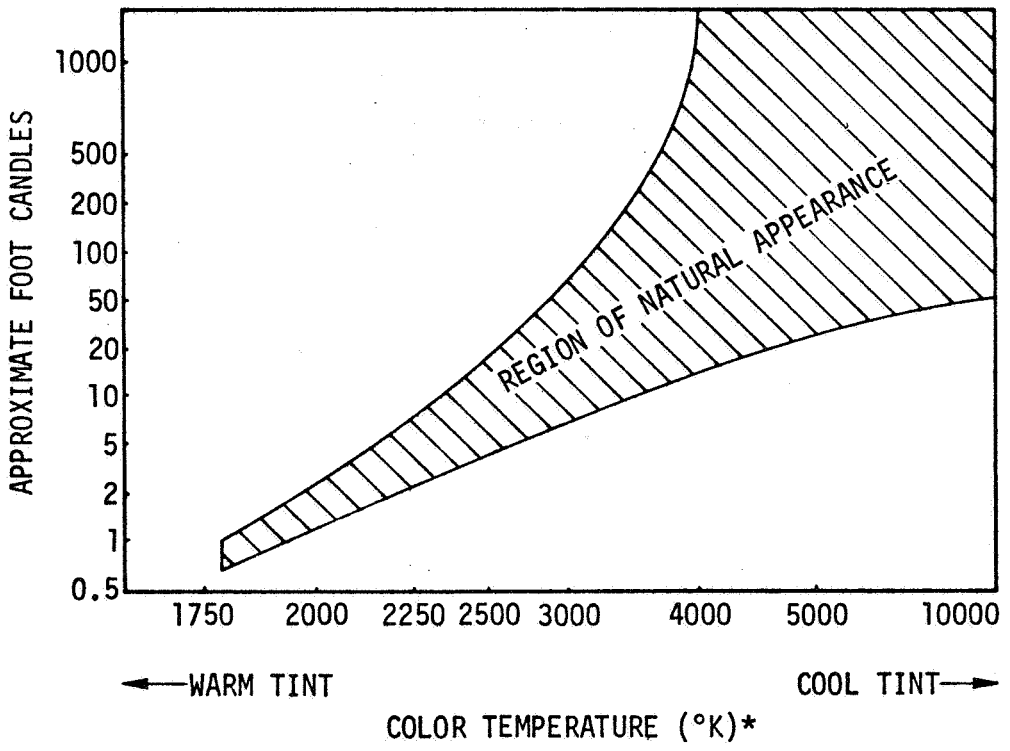
	Incandescent Lamps		High Intensity Discharge Lamps			
	Filament	Clear Mercury	White Mercury	Deluxe White	Multi-Vapor**	Lucalox*
Lamp appearance effect on neutral surfaces	Yellowish white	Greenish blue-white	Greenish white	Purplish white	Greenish white	Yellowish
Effect on atmosphere	Warm	Very cool, Greenish	Moderately cool, Greenish	Warm Purplish	Moderately cool, Greenish	Warm Yellowish
Colors strengthened	Red Orange Yellow	Yellow Green Blue	Yellow Green Blue	Red Yellow Blue	Yellow Green Blue	Yellow Orange Green
Colors grayed	Blue	Red Orange	Red Orange	Green	Red	Red Blue
Effect on complexions	Ruddiest	Greenish	Very pale	Ruddy	Grayed	Yellowish
Remarks	Good color rendering	Very poor color rendering	Moderate color rendering	Color acceptance similar to CW fluorescent	Color acceptance similar to CW fluorescent	Color acceptance approaches that of WW fluorescent

*Greater preference at lower levels

**Greater preference at higher levels

Table 4-16. Kelvin Color Temperatures of Fluorescent Lamps

Lamp Color Name	Color Temperature (°K)
Warm White	3000
Deluxe Warm White	2900
White	3500
Cool White	4200
Deluxe Cool White	4200
Sign White	5200
Daylight	7000



*See Table 4-16 for °K of fluorescent lamps.

Figure 4-11. Kruithof's Principle

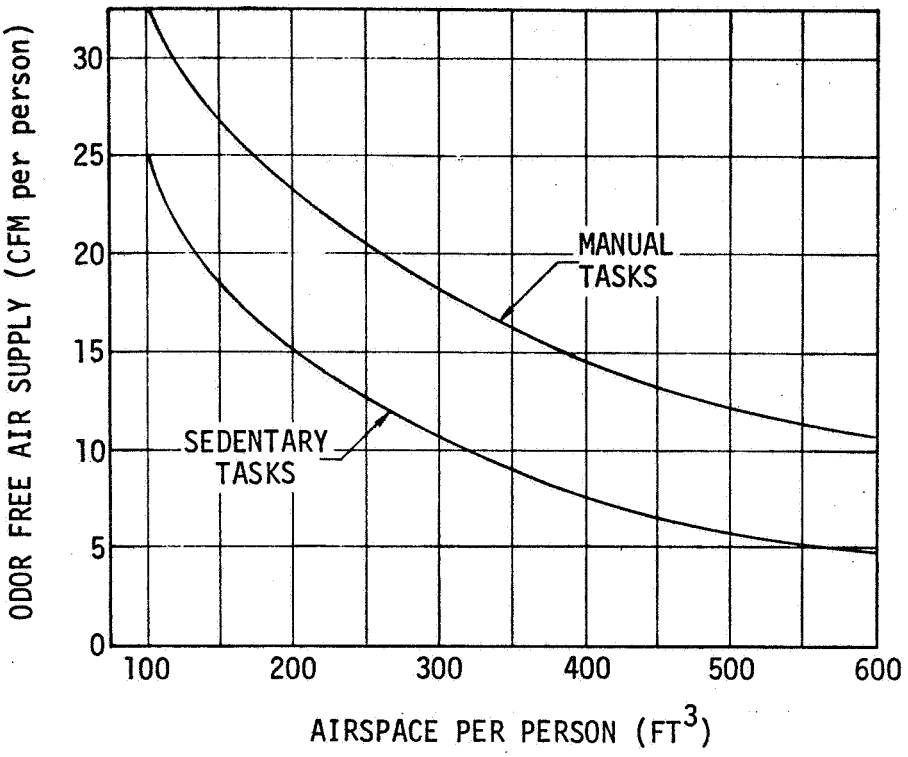


Figure 4-12. Minimum Odor-Free Requirements to Remove Objectionable Body Odors

REFERENCES

NOTE

The primary source of data for this handbook was Reference 1. Data extracted from Reference 2 are noted in the text.

1. "Architectural/Environmental Handbook for Extraterrestrial Design," Martin Marietta Corporation - Denver Division - Report MCR-70-446, November 1970.

2. Kryter, K. D. et.al., "Hazardous Exposure to Intermittent and Steady-State Noise," J. Acoust. Soc. Amer., 39, 3 November 1966.

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